The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association
Western Orthopedic Association

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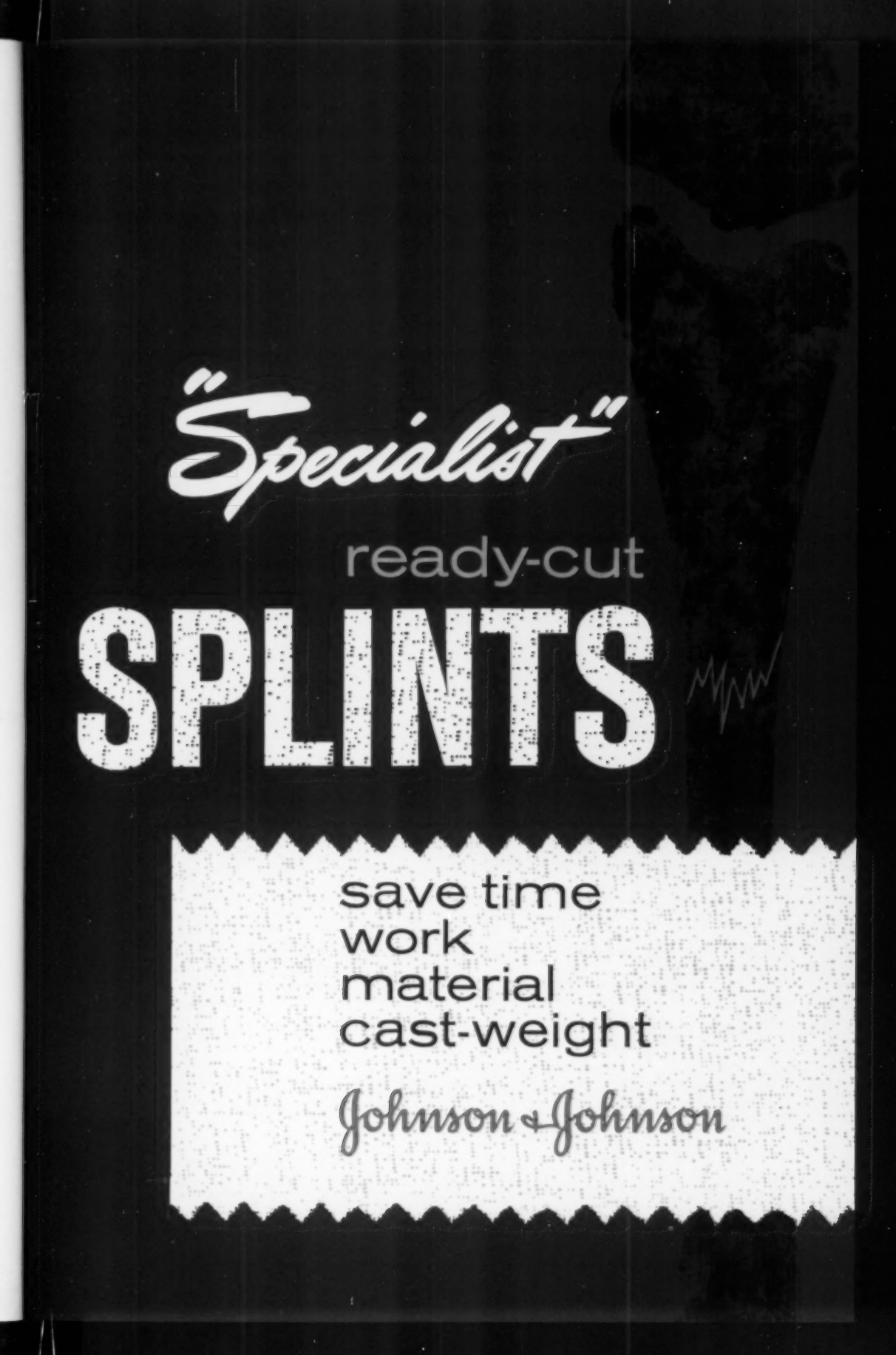
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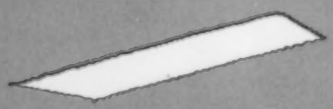

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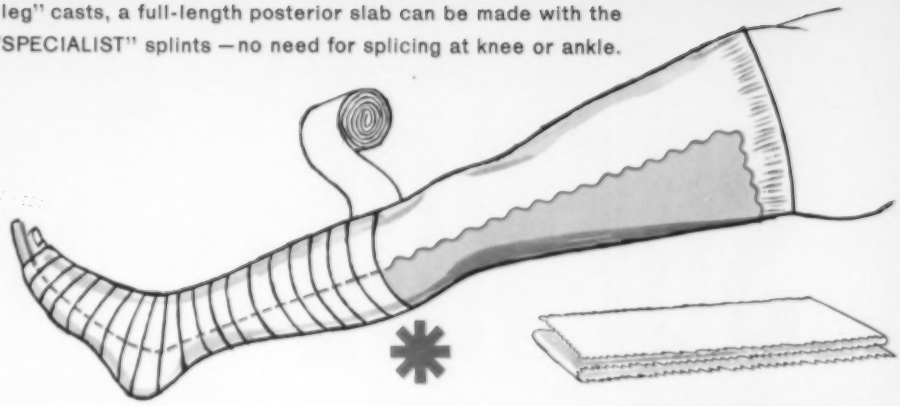

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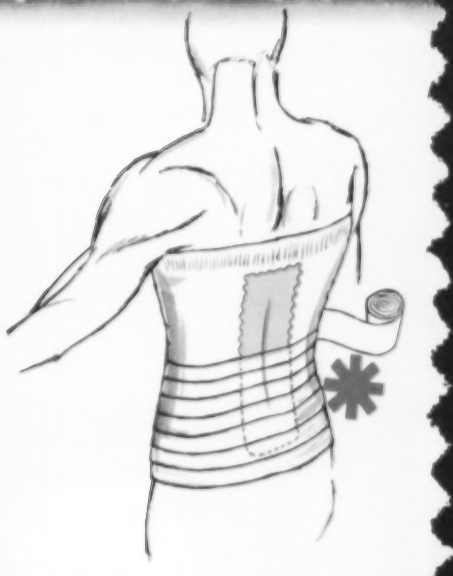

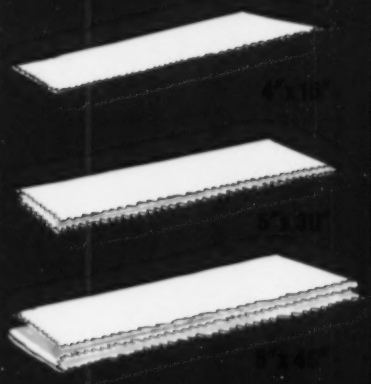

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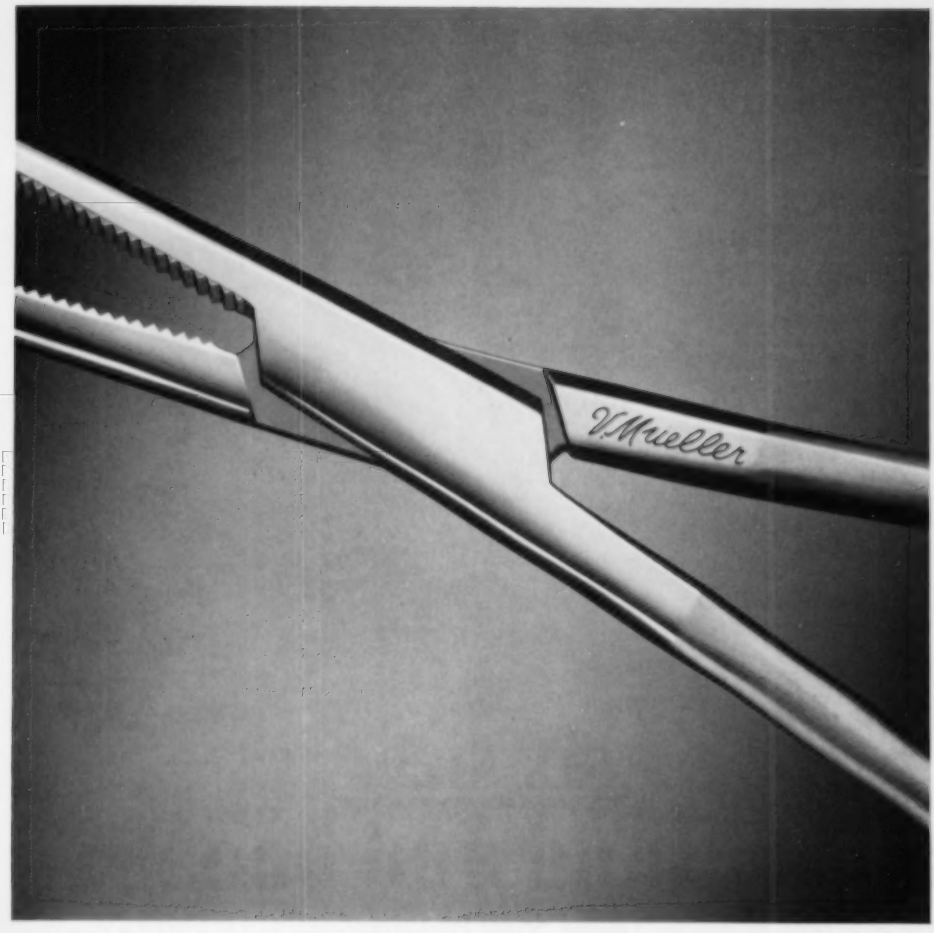

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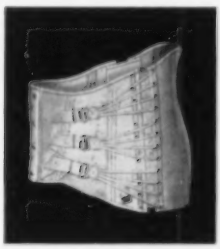

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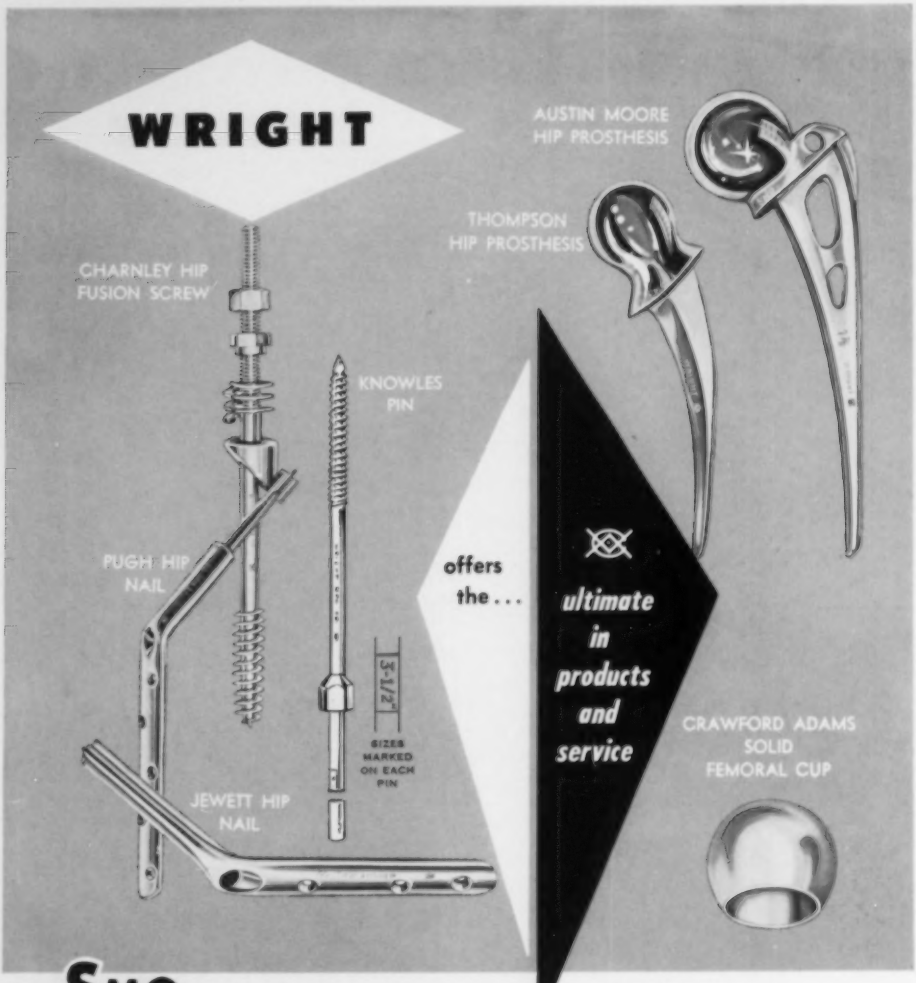

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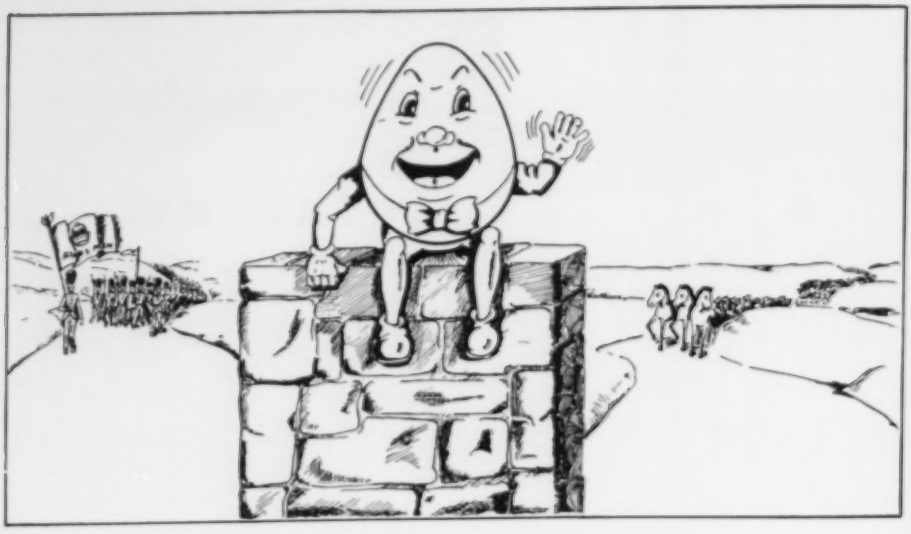

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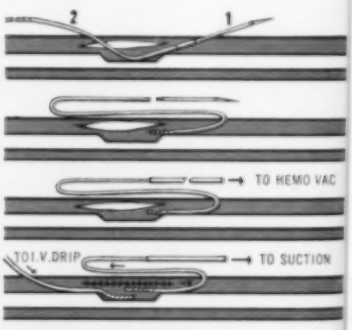

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LOOK FOR THE TRADEMARK Ⓩ

Developed and manufactured by Snyder Mfg. Co., Inc., New Philadelphia, Ohio
Distributed exclusively by Zimmer Manufacturing Co., Warsaw, Indiana, U. S. A.

vertebral bracing

plus COMFORT and COSMETIC APPEAL with SPENCER INDIVIDUAL DESIGNING

This patient with initial fracture of sacrum sustained subsequent whiplash injury with accompanying sprain in lower lumbar area. Resulting vertebral injury limited bending and walking. Her Spencer Support and heat therapy were prescribed to sustain her in daily activity and endorsed by orthopedic consultant.

Spencer first realigns the body with adjustable measuring garment — then designs a support to hold it that way. Each Spencer Support is designed individually to meet patient requirements, incorporating features prescribed. Comfort and cosmetic appeal assure patient acceptance.

Spencer's Individual Designing Service is available to you through Corsetieres specially trained to help you help your patients.

MAIL COUPON TODAY →

SPENCER®

supports individually designed for women, men and children

SPENCER, INCORPORATED
19 Ellsworth Ave., New Haven 7, Conn.
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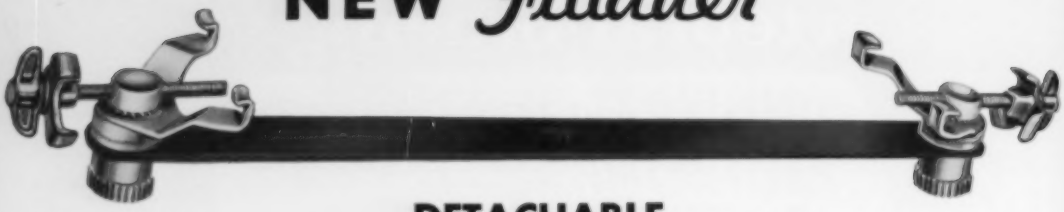
☐ Send me the new booklet guide to Spencer prescription service.
☐ I would like an office demonstration of Spencer.

Name _____

Address _____

10-60

NEW *Fillauer*



DETACHABLE

DENIS BROWNE NIGHT SPLINT

STREAMLINED and IMPROVED

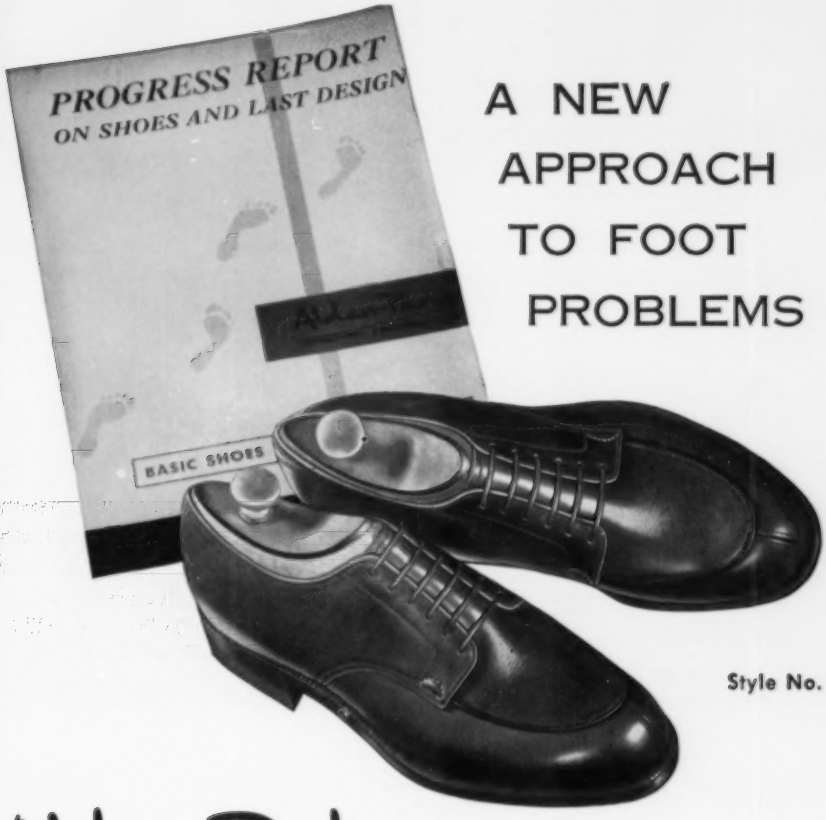
1. Precision die cast Serrated Discs permit 50 positions.
2. New Knurled Screw locks discs in position.
3. New Triple Flange fits club foot shoes or any sole thickness.
4. Streamlined Wing Screw secures flange to shoe sole.
5. Durable, attractive red alumilite color on bars.
6. Lengths 6, 7, 8, 9, 10, 12, 14, 16 and 18 inches. Special lengths to 30 inches at no extra cost.

ORTHOPEDIC SURGEONS recognize the decided advancements this versatile splint affords in treating club feet, positional deformities, tibial torsions, flat feet and congenital hip dislocations. Also applicable for any other deformities that are actively corrected by incessant kicking.

Very little adjustment by surgeon or orthotist is required to fit and position this new Fillauer Detachable Splint.

Pre-walker or larger surgical and club foot shoes work extremely well with the Fillauer Splint. Outgrown shoes may be used by cutting out toes.

Fillauer SURGICAL SUPPLIES, INC.
BOX 1678 CHATTANOOGA, TENN.
ESTABLISHED 1914 *Manufacturers of Orthopedic Supplies*



A NEW APPROACH TO FOOT PROBLEMS

Style No. 84

Alden-Pedic SCIENTIFIC CONSTRUCTION SHOES

Preferred by the Nation's Leading Foot-Fitting Specialists

- Long inside counter
- Right and left ortho heels, long inside
- Heavy gauge right and left ribbed steel shank.
- New "Depth Design" accommodates prescribed corrections

WRITE FOR BOOKLET AND NAME OF NEAREST DEALER

Alden-Pedic lasts and shoes serve 3 purposes:

- Fit the individual foot shape . . .
- Accommodate your prescribed corrections . . .
- Provide a stable, controlled foundation.

Write us today for our new illustrated brochure of Alden-Pedic styles for men and boys and our new "Progress Report on Shoe and Last Design."

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Custom Bootmakers Since 1884

BROCKTON, MASSACHUSETTS

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

why undertake femoral head replacement?

Restoration of function and relief of pain are the dual management objectives in hip pathology.[1] Although in the past nailing the viable head of the femur was often preferred, the disadvantages of long postoperative disability and frequently poor final results have led to an ever wider usage of prosthetic arthroplasty. In replacement therapy surgical complications, morbidity and mortality have become minimal.[2] Moreover, with prostheses the "disappointments of aseptic necrosis and mechanical failure . . . have been avoided."[2]

After the failure of the acrylic Judet prostheses, the development of anatomically-correct, physiologically-inert, weight-bearing femoral head replacements stimulated a renewed interest in prosthetic arthroplasty.

Well over a thousand published case reports[1-24] of femoral head replacements with Vitallium prostheses sharply delineate the advantages of this procedure. The following timetable applies to a series of 45 cases,[1] but is typical for most of the published reports and is considered conservative by some.

1. Postoperative period uneventful.
2. Traction removed within 48 hours.
3. Dangling after five days.
4. Sitting in chair 7-10 days after surgery.
5. Weight-bearing with help after 11 days.
6. Hubbard tub every other day, starting 2 days after removal of sutures.

With hip arthroplasty a shorter hospital stay and convalescent period is made possible, requirements for nursing care are reduced, and the need for secondary surgical procedures is rare. Femoral head replacement eases the patient's economic burden, gives him a greater degree of physical independence, does away with pain and limp in the majority of cases, and enables many patients to return to an active, useful life.[1-4, 6, 10, 18, 20-22]

INDICATIONS:

Acute fractures in the aged
Un-united, long-term fractures
Delayed non-union
Acute unstable fracture (Pauwels' 3)
Aseptic and avascular necrosis
Osteoarthritis
Bilateral ankylosis
Rheumatoid arthritis
Salvage
Pathologic fractures

(Left) Severe arthritic involvement of both hips in 64-year-old white male. (Right) Bilateral insertion of Moore Vitallium Self-locking Hip Prostheses restores patient's walking ability.

"...the Austin Moore intramedullary Vitallium prosthesis [is] one of the best prostheses available at the present time."[1]

Only Austenal Surgical offers the full range of prosthetic hip replacements. The Vitallium Moore Prosthesis, Cat. No. 6939, is available in head diameters from 1½" to 2¼", in ⅛" increments. The Vitallium Modified Moore Prosthesis, Cat. No. 6939-1, has a slightly narrower stem. For Moore instruments, please consult your Austenal catalog, section III, page 5.

REFERENCES: 1. Matchett, F.: Rocky Mountain M. J. 56:47, 1959. 2. Mahoney, J. W. et al.: Am. J. Surg. 95:577, 1958. 3. Breck, L. W.: Southwestern Med. 35:207, 1954. 4. Savastano, A. A. et al.: Rhode Island M. J. 41:425, 1958. 5. Ghormley, R. K.: Rocky Mountain M. J. 54:337, 1957. 6. Barker, W. E.: Manitoba Med. Rev. 38:673, 1958. 7. Symposium on Femoral Head Replacement Prostheses, J. Bone & Joint Surg. 38A:407, 1956. 8. Thompson, J. E. M.: Surg. Gynec. & Obst. 96:301, 1953. 9. Bohlman, M. R.: Am. J. Surg. 84:268, 1952. 10. Bascom, J. et al.: J.A.M.A. 169:1863, 1959. 11. Coventry, M. B.: Surg. Gynec. & Obst. 109:243, 1959. 12. Thompson, F. R.: New York State J. Med. 52:3011, 1952. 13. Moore, A. T.: J. Bone & Joint Surg. 39A:811, 1957. 14. Thompson, F. R.: In Acad. Orthop. Surg. Instructional Course Lectures, vol. 16, C. V. Mosby, 1959, p. 299. 15. Moore, A. T.: In Acad. Orthop. Surg. Instructional Course Lectures, vol. 16, C. V. Mosby, 1959, p. 309. 16. Thompson, F. R.: J. Bone & Joint Surg. 36A:389, 1954. 17. Stinchfield, F. E., et al.: J. Bone & Joint Surg. 39A:1043, 1957. 18. Peterson, L. T. and Raad, M. A.: Med. Ann. D. C. 24:233, 1955. 19. Gaenslen, F. G.: Wisconsin Med. J. 59:181, 1960. 20. Hart, G. M.: J. Lancet 78:369, 1958. 21. Carlander, L. W.: Minnesota Med. 42:566, 1959. 22. Beegel, P. M.: J. Maine M. A. 49:86, 1958. 23. Moore, A. T.: South. M. J. 45:1015, 1952. 24. Day, P. L. and Hinchey, J. J.: Clin. Orthop., No. 6, p. 27, 1955.

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Surgical Appliances

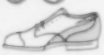
AUSTENAL COMPANY SURGICAL PRODUCTS

DIVISION OF HOWE SOUND COMPANY • 224 EAST 39th STREET, NEW YORK 16, N. Y.

The Complete Line of 's that 's Refer and ℞

MEDIC is proud that everyday more and more 's are recommending Junior Arch Preserver s to meet their patient's ℞s. There is no

why these shoes are recommended, 4 MEDIC not only offers top quality and fit, but combines this with style and a complete line to meet every need.

Beside MEDIC 's Regular Construction , there's the Junior Arch Preserver WedgeTred 4 additional support and prevention . . . Long Counter Thomas Heel 4 mild pronation . . . Inflare Last 4 extreme pronation . . . mild Outflare Last 4 mild pigeon toe . . . Outflare Last 4 extreme varus . . . Straight Last and also with  and 4 varied ℞ needs . . . Surgical Boot 4 braces . . . Pre-Walkers 4 congenital disorders. As U can , MEDIC makes a shoe to fill every 's ℞ requirements.

Developed after years of studies . . . designed exclusively for congenital disorders when indicated by the doctor.

For the name and address of the store nearest you carrying Junior Arch Preservers, write today to

MEDIC SHOE MANUFACTURERS, INC.
1212 Wood Street, Philadelphia 7, Pa.

First emphasis is on
PAIN RELIEF
in the low back syndrome

not only *relieves pain* but also *relaxes taut muscles*

SAFE POTENT FAST

SOMA®

(carisoprodol Wallace)

Samples and literature on request

WALLACE LABORATORIES, Cranbury, New Jersey

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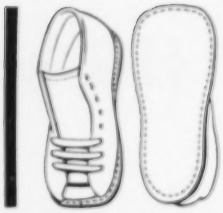
Look to the shoes



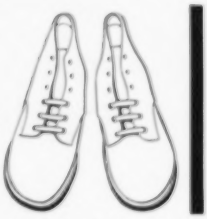
Pre-Walker, reverse or straight last

that have earned the

Pigeon-Toe, for mild supination

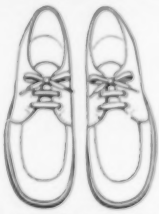
Super-Pedic, for extreme pronation

confidence of the medical profession.



Prona-Pedic, for extreme supination

CorecTreds and Pedics by Edwards



CorecTred, for mild pronation

Thomas Heel Extended Counter

For over 60 years **Edwards** has sought to develop a *complete line* of fully adaptable, quality shoes, at sensible prices, to meet doctors' special prescription requirements. Using tested lasts from clinic-approved patterns, **Edwards** experienced craftsmen developed CorecTreds and Pedics, the most versatile shoes available, sold by conscientious retailers trained in prescription fitting.

Whatever your prescription requirements, examine and advise CorecTreds and Pedics by **Edwards**!

Edwards
THE SHOE FOR CHILDREN
PHILADELPHIA 7, PA.

FREE EDWARDS NEW PEDIC KIT

Now, receive Edwards new, complete Pedic Kit designed especially for you. It contains:

- WEDGE CHART
- PEDICGRAPH
- PRESCRIPTION PADS
- CORECTRED FOLDERS
- PEDIC BROCHURES
- HAPPY FEET BOOKLET

Simply Detach This Portion of Advertisement, Mail With Your Personal Letterhead to Edwards Shoes, 314 N. 12th St., Phila. 7, Pa.

INSIST ON THE
AUTHENTIC

Non-rotating trifin nail retractable 1¾". Overall nail length 4¾".

•

Plate (forged) lengths, 1" to 6" in 1" increments.

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Precision pre-set frictional resistance. No additional adjustments or tools are required.

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135° angle. Special angles and special driver sleeves also available.

ACCESSORIES

Driver with driving sleeve.

½" Cannulated reamer with removable stop.

½" Cannulated reamer without stop.

*The Dr. Willis L. Pugh, original developer, technical reprint available upon request.

PUGH*
SELF-ADJUSTING
HIP NAIL

EXCLUSIVELY
by Orthopedic

SPECIFY
SMO AISI 316-317

The superiority of wrought or forged metals for internal fixation units is well established . . . "AISI 316 and 317 stainless steel has borne the test of time commendably in the field of surgical implants . . . The corrosion resistance of AISI 316 and 317 stainless steel is very satisfactory under most conditions."

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By Drs. Charles O. Bechtol, Albert B. Ferguson, Jr. and Patrick G. Laing. (Williams and Wilkins—1959)

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BOURBON • INDIANA
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Your Sign of Quality

OEC products shipped to the 50 United States and 49 foreign countries from Baffin Bay to the Bay of Bengal.

Want a trouble-free adhesive?

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And here's how you save when you buy CURITY quality!

When all the final costs are in, you'll find *Curity* WET-PRUF provides the true economy.

Made with proper, easy-to-tear body, this tape averts the waste of twisting and tangling. It is water and soil resistant. Holds fast, looks clean, despite sweating or washing.

WET-PRUF retains its freshness. You use the full length of tape. It unwinds smoothly, clear down to the core. See your *Curity* representative about WET-PRUF and the complete line of *Curity* adhesives.

CURITY... the other word for quality

Curity ADHESIVES

THE KENDALL COMPANY
BAUER & BLACK DIVISION

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another Zimmer First

CERTIFIED ZIMALOY PROSTHESIS

Model: Thompson Type
Serial No. G 458
(Certification for Moore type available)

Material: Zimaloy
(Cobalt-Chromium-Molybdenum Alloy)

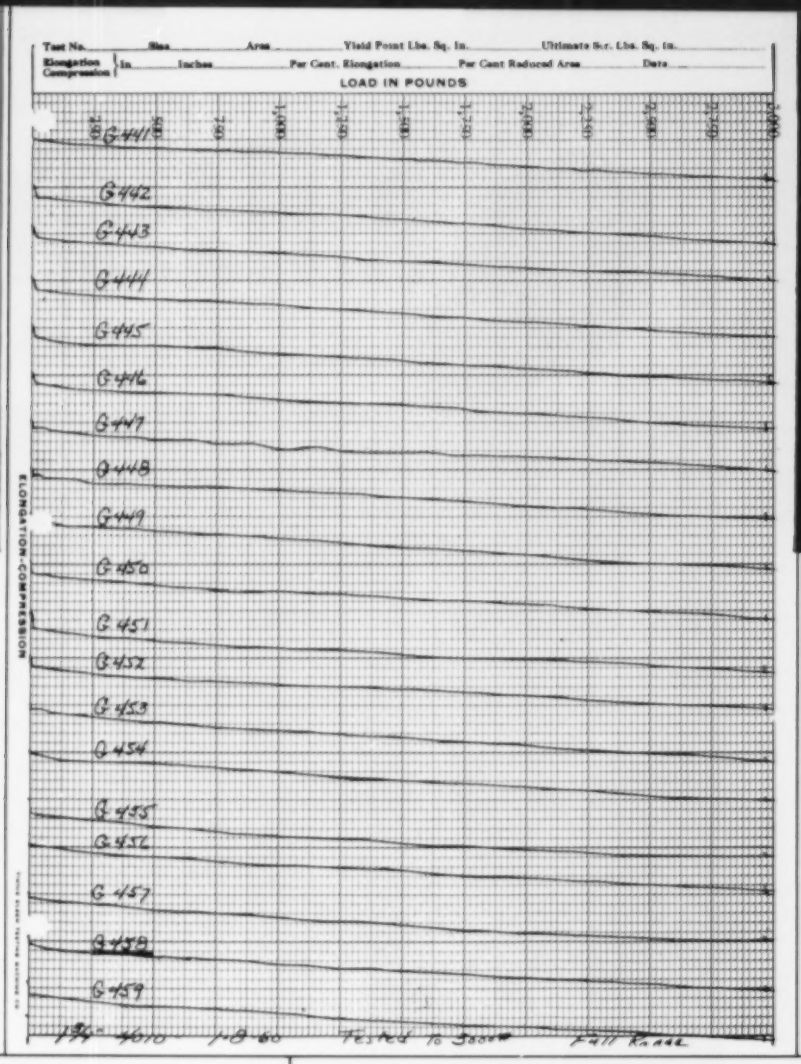
G458

Quality Control:

1. Each casting is X-rayed for internal soundness.
2. A notarized Material Certification is furnished by supplier. This certification which covers the chemical and mechanical test results of the metal, also certifies 100% X-ray and Zyglo Pentrex testing.
3. Each Zimaloy prosthesis undergoes a Non-destructive Mechanical Test. The Thompson Type is subjected to a standard direct load of 3,000 lbs. This standard load is safely below the elastic limits and does not weaken a sound prosthesis. If the prosthesis is unable to withstand this load a downward curve will develop on the chart which will indicate a weakness or defect.
4. A Zyglo bath is performed to detect surface flaws or defects not visible to the eye.
5. Each head is gaged for correct diameter.
6. Each prosthesis is visually inspected before being approved and sent to the stock room.

Certified Permanent Record:

Each Thompson Type prosthesis is etched with a permanent serial number which appears on its X-ray, the Material Certification, the mechanical test graph, and the final inspection report. There is a permanent record kept of each prosthesis which contains the certifications listed above. At any time in the near or distant future this record can be produced showing the date that the prosthesis was manufactured, the X-ray and all of the other certifications of its satisfactory quality. This is truly a prosthesis with a pedigree, another Zimmer first.



ZIMMER MANUFACTURING COMPANY
Warsaw, Indiana, U.S.A.

MATERIAL CERTIFICATION

TO: Zimmer Mfg. Co.
Warsaw, Indiana

DATE: December 30, 1959

ATT:

MATERIAL SPECIFICATION	CUSTOMER ORDER NO.	PART NO.	DATE SHIPPED	QUANTITY SHIPPED	PACKING SLIP NO.
Stanley	C6731	4010 1-3/4" Thompson Pros. shank	12/30/59	20	3457-698-B

CHEMICAL ANALYSIS — Serial No. G441 through G460

MASTER HEAT NO. A250 LOT NO. 1613

C	Si	Mn	P	S	Cr	Ni	Fe	Mo
.37	.51	.63	.010	.011	27.52	1.86	.32	6.53

TEST RESULTS

ULTIMATE STRENGTH PSI	YIELD STRENGTH PSI	% ELONGATION	% RED. OF AREA	HARDNESS
127,300	76,380	10.0	10.3	30.5

XRAY 100% MAGNAFLUX Not Required ZYGLO Pentrex 100%

Remarks: As Cast

Chicago Spectro Service Laboratory, Inc.

WE CERTIFY THAT THE PARTS CONTAINED IN THIS SHIPMENT HAVE BEEN FABRICATED TO CONFORM TO YOUR SPECIFICATION AS NOTED

Subscribed and sworn to before me this 30 day of December, 19 59

Wendell D. Yeh
Notary Public

My commission expires Feb 4, 1961

By H. J. Zabelka
H. J. Zabelka, Chief Met.

No. 9841A

ZIMMER MANUFACTURING COMPANY
MATERIAL DISPOSITION AND INSPECTION REPORT

DATE:	INSPECTION: high / outside / processing / final / receiving / line	PART NAME AND NUMBER	ENG. CHANGE
2-23-60			
PUR. ORDER NO. C 6731		#4010 1-3/4" Thompson type Prostheses	

VENDOR	ADDRESS			
Zimmer Mfg. Co., Warsaw, Indiana				
RECEIVING REPORT NO.	P.O. NO.	QUAN. RECEIVED	QUAN. INSPECTED	QUAN. DEFECTIVE
		20	20	None

20 pcs. of the following serial numbers have been delivered to the shipping department. All castings have passed mechanical test, radiographic, Zyglo, and visual examination. Certification of chemical analysis of material used is on file and conforms to engineering specifications.

G441 G442 G443 G444 G445 G446 G447 G448 G449 G450 G451 G452

G453 G454 G455 G456 G457 G458 G459 G460

INSTRUCTIONS AND REMARKS:

DISPOSITION: ACCEPT	REJECT	RETURN	SCRAP	MAT. REVIEW	SALVAGE	APPROVAL: INSP.	ENG.	INSPECTOR
20								

cc: MDIR
#4010

ZIMMER MFG. CO.

SIMMONS INVENTS A NEW MATTRESS— BACK CARE WITH BUILT-IN BEDBOARD

For firm support—the new-type bedboard centered in the mattress, *close to the back*, firmly supports spinal structures.

For "sag" control—the lower layer of springs pushes up against the bedboard and prevents "sagging" at any point.

For sleeping comfort—the upper layer of springs adjusts to body contours.

The unique construction of Back Care—including the new "Ortho-Fiber" bedboard—was suggested by physicians who stressed the need for a mattress especially adapted to the requirements of patients with chronic backache.

Back Care has been tested and approved by a group of leading orthopedic surgeons. They found that it affords patients both the firmness and the comfort necessary to alleviate backache caused or aggravated by lack of proper mattress support.

Many physicians have endorsed Back Care With Built-In Bedboard, as a basic adjunct to the management of chronic, uncomplicated backache.

For complete information on Back Care—with special reference to its orthopedic features—write for the descriptive booklet from Simmons Co., Dept. AA, Merchandise Mart, Chicago, Illinois.

BACK CARE by SIMMONS

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

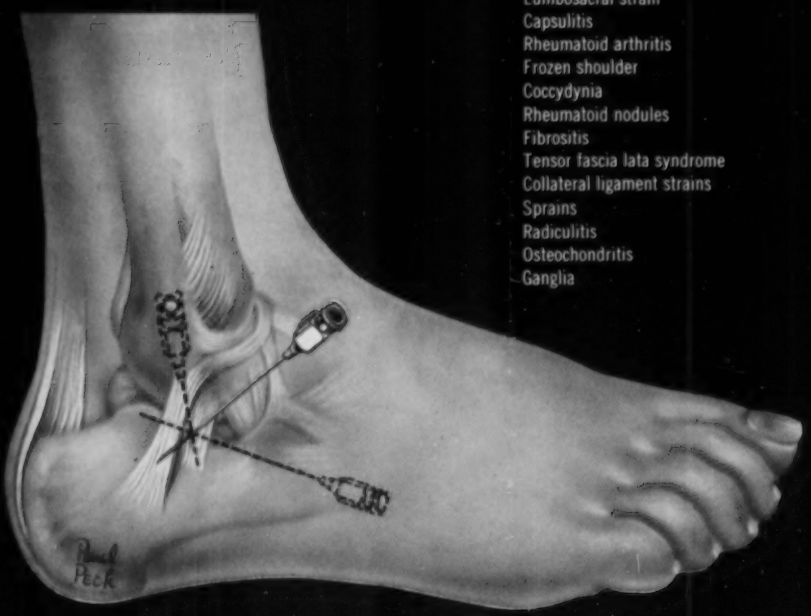
HYDELTRA® -T.B.A.

(Prednisolone *tertiary*-butylacetate, Merck)

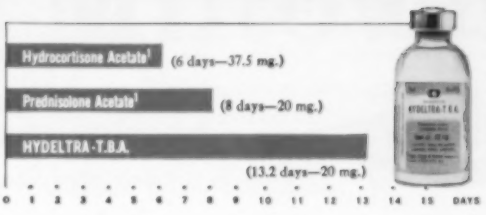
for relief that lasts—longer

in *SPRAINS*—
reduces tenderness,
swelling and
limitation of motion

Osteoarthritis
Acute gouty arthritis
Bursitis
Tendinitis
Trigger finger
Peritendinitis
Trigger points
Tennis elbow
Lumbosacral strain
Capsulitis
Rheumatoid arthritis
Frozen shoulder
Coccydynia
Rheumatoid nodules
Fibrositis
Tensor fascia lata syndrome
Collateral ligament strains
Sprains
Radiculitis
Osteochondritis
Ganglia



Anti-inflammatory effect lasts longer than that provided by any other steroid ester


Hydrocortisone Acetate[1]
(6 days—37.5 mg.)
Prednisolone Acetate[1]
(8 days—20 mg.)
HYDELTRA-T.B.A.
(13.2 days—20 mg.)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 DAYS

Dosage: the usual intra-articular, intra-bursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

Supplied: Suspension 'HYDELTRA'-T.B.A.—20 mg./cc. of prednisolone *tertiary*-butylacetate, in 5-cc. vials.

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PROGRESSIVE LEADERSHIP

...IN BASIC FOOTWEAR

PLUMB-LINE SURGICAL
Perfect for brace work and special shoe work.

PLUMB-LINE BOOT
From baby through misses sizes 3½ to 12½.
White, tan, or shark tip.

PLUMB-LINE OXFORD

The **original,** truly straight last with no inward or outward flare. The basic shoe from which to build corrections. Squared-off forepart to correct impingements on small toes.

SABEL'S PLUMB LINE
TRADE MARK REG U.S PAT OFF.

by Walkin Shoe Co.
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THE MOST COMPLETE PROGRAM IN THE ORTHOPEDIC FIELD

Sabel covers every prescribed correction with the **right** shoe . . . Equino-Varus, Surgical, Night Splint or Center-Line Brace and Walking Shoe.

SABEL'S EQUINO-VARUS
TRADE MARK REG U.S PAT OFF.

Brace attaches directly to the sole of the shoe, sets accurately, neater, simpler . . . a Sabel exclusive. Interchangeable with Fillauer Night Splint. Both available from stock department.

by R. J. Potvin Shoe Co., Brockton, Mass.

Proven

in over five years of clinical use and
more than 750 published clinical studies

Effective

for relief of anxiety and tension

Outstandingly Safe

- simple dosage schedule produces rapid, reliable tranquilization without unpredictable excitation
- no cumulative effects, thus no need for difficult dosage readjustments
- does not produce ataxia, change in appetite or libido
- does not produce depression, Parkinson-like symptoms, jaundice or agranulocytosis
- does not impair mental efficiency or normal behavior

Miltown®

meprobamate (Wallace)

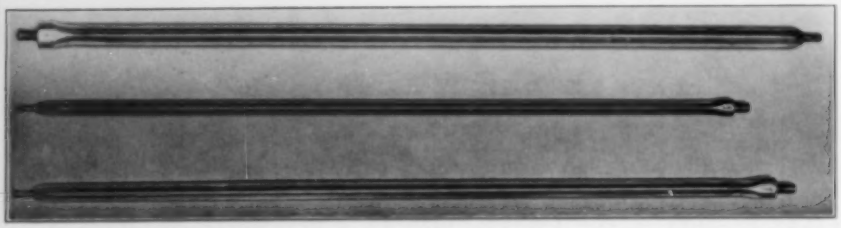
Usual dosage: One or two 400 mg. tablets t.i.d.
Supplied: 400 mg. scored tablets, 200 mg. sugar-coated tablets; or as MEPROTABS®—400 mg. *unmarked*, coated tablets.

OM-2058

WALLACE LABORATORIES / *Cranbury, N. J.*

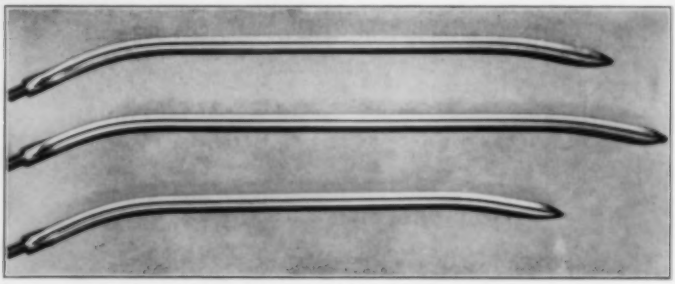
®TRADE-MARK

LOTTES NAILS and INSTRUMENTS

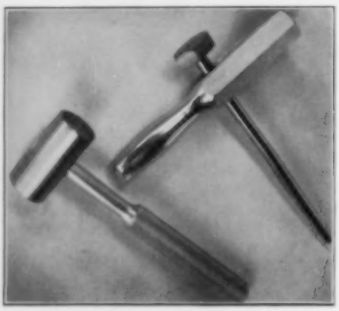


***LOTTES* FEMORAL NAILS** are manufactured with diameters of 3/8, 7/16, and 1/2 inches —with lengths in 1/2 inch variations from 14 to 20 inches.

***LOTTES* TIBIAL NAILS** are made in 5/16 and 3/8 inch diameters—in lengths from 9 to 15 1/2 inches, in variation of 1/2 inch.



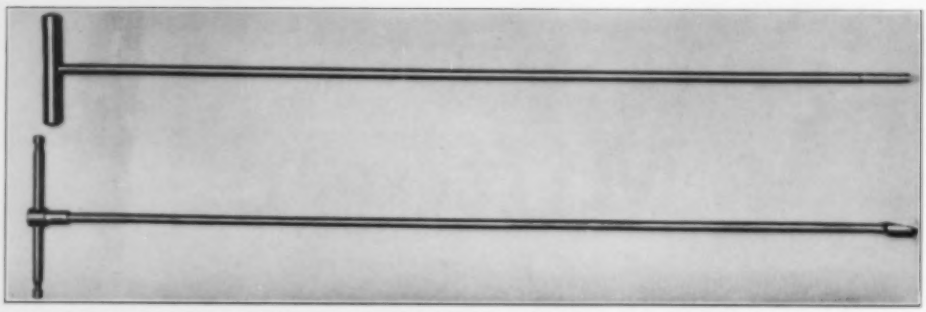
***LOTTES* NAILS AND INSTRUMENTS ARE MADE OF 18-8 SMo STAINLESS STEEL**



***LOTTES* DRIVER-EXTRACTOR COMBINATION and *LOTTES* MALLET**

***LOTTES* GUIDE WIRE AND *LOTTES* REAMER**

The reamer comes in 3 diameters: 3/8, 7/16, and 1/2 inch—all are 23 inches in length.



CHAS. A. SCHMIDT SURGICAL INSTRUMENT COMPANY

3689 Olive Street, Saint Louis 8, Missouri

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FOR THAT EXTRA MEASURE OF RELIEF
IN SEVERELY PAINFUL RHEUMATIC AND TRAUMATIC DISORDERS

NEW

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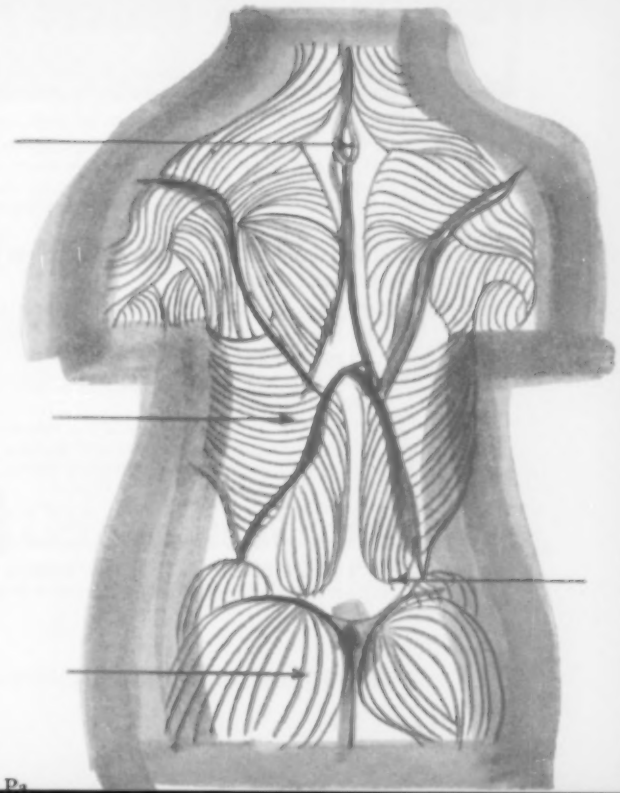

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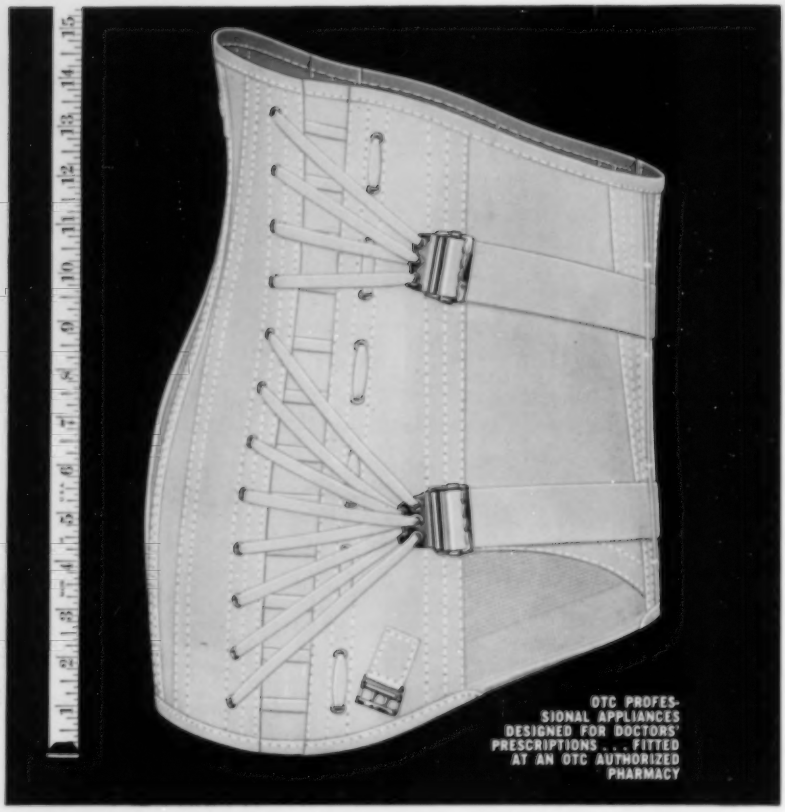

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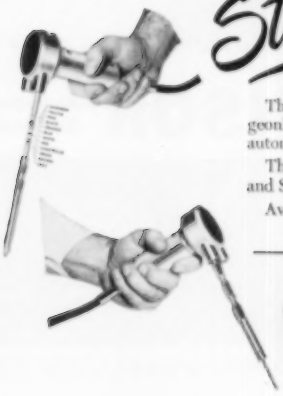

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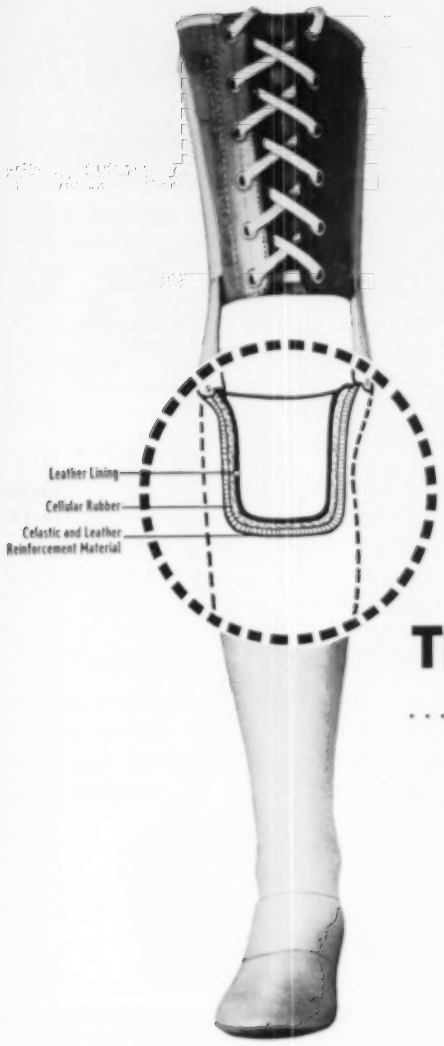

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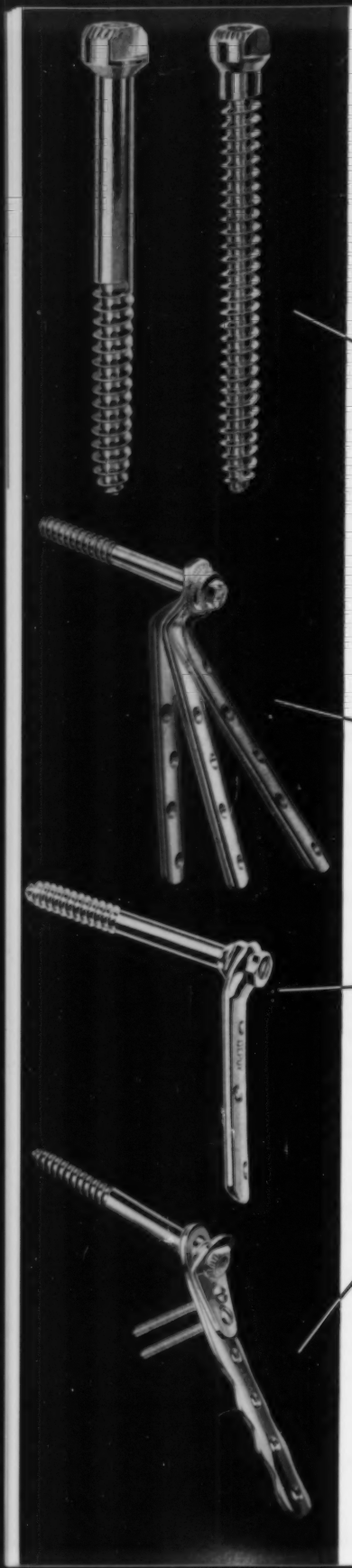

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Management of Fractures of the Greater Multangular

Report of Five Cases*

BY LEE J. CORDREY, M.D., TAMPA, FLORIDA, AND MIGUEL FERRER-TORELLS, M.D.†, MADRID, SPAIN

Fractures of the greater multangular occur in about 5 per cent of all fractures of the carpal bones. Since the first carpometacarpal joint is important in the function of the thumb and in the performance of strong pinch and grasp, injury to the greater multangular, if not accurately diagnosed and treated, may lead to permanent impairment of function because of pain, limitation of motion, or weakness. Scant attention has been given to the management of fractures of the greater multangular in standard textbooks on fracture treatment. The purpose of this paper is to present the results of a survey of reported fractures of the greater multangular and the authors' experience in the management of these injuries.

HISTORICAL REVIEW

In 1910 Kindl reported a fracture of the greater multangular associated with a Bennett fracture. Since that time approximately seventy-five fractures of this carpal bone have been reported in the world literature. Of these, thirty-nine were isolated fractures and the mechanism of trauma was almost evenly divided between direct violence to the wrist and hand and falls on the hyperextended hand [1–5,7,9,10,11,12,14,16,19,20,21,23–30,32]. Köhler wrote that isolated fractures of the greater multangular are rare, are almost impossible to produce experimentally, and are usually associated with other injuries about the wrist. Fracture of the first metacarpal is the most common associated injury [8,11,22] and fracture of the distal radius, the next most common [31]. Kindl and Destot attempted to produce fractures of the greater multangular experimentally by force transmitted through the thumb; however, fracture of the thumb or of the posterior lip of the radius usually resulted from this trauma. Jeanne and Mouchet and Manon demonstrated in cadavera that the greater multangular is strongly compressed by the radial styloid process and the base of the first metacarpal on radial deviation of the wrist and considered this the mechanism of importance in the production of isolated fractures.

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 22, 1960.

† Dr. Miguel Ferrer-Torells was a Resident in Orthopaedic Surgery at University Hospitals, Cleveland, Ohio, at the time of this collaboration.

There was wide variation in the management of the reported multangular fractures, ranging from unrestricted motion of the hand with adjuvant physical therapy to partial excision of the fracture fragments. It was found impossible to grade these injuries as to degree of severity from the published roentgenograms or to determine the efficacy of the treatment rendered. In more than 60 per cent of all the reported cases, however, there was noted either persistent pain, swelling, or limitation of motion of the wrist and thumb at the conclusion of treatment. In no reported instance was operative reduction with internal fixation advocated.

ANATOMY

The greater multangular is trapezoid in form and has four surfaces which bear hyaline cartilage for articulation with the first and second metacarpals, the lesser multangular, and the scaphoid. The dorsal surface bears a well defined ridge or tubercle over which pass the extensor pollicis brevis and longus tendons. The radial and volar surfaces of the bone are covered by the thenar muscles and the flexor pollicis longus tendon.

The most important articulation of the greater multangular is with the first metacarpal. Stability of this joint is afforded, in part, by the capsule, which is reinforced on its dorsal and volar aspects by ligamentous bands and on its radial aspect by the tendon of the abductor pollicis longus. The first carpometacarpal articulation is a loosely fitting saddle-joint which permits three types of motion: (1) flexion and extension, (2) abduction and adduction, and (3) rotation. The combined motion at this joint allows the thumb to be moved through an arc which extends from extension through abduction to flexion. Damage to the articular surfaces or to the capsule of the joint tends to restrict all components of this combined motion.

There are no significant motor nerves in relation to the greater multangular. The radial sensory nerve to the thumb is situated lateral to the first carpometacarpal joint. The radial artery courses over the dorsum of the greater multangular and then passes between the bases of the first and second metacarpals through the first dorsal interosseus muscle into the palm.

CLINICAL FINDINGS

Patients with fractures of the greater multangular frequently give a history of a direct blow to the radiodorsal aspect of the wrist. The most striking clinical feature is the relative lack of discomfort; the major complaint of patients with this fracture was a sensation of weakness of the thumb with maximum discomfort on attempted pinch. On examination, there was usually no gross deformity, although a fairly marked degree of swelling was often observed. Motion of the wrist was not markedly restricted and there was no gross limitation of motion of the fingers. Palpation over the anatomical snuff box invariably produced pain, but crepitus was rarely noted. Motion of the thumb was usually possible through all but the last ranges of opposition. As a rule, it was impossible for the patient to sustain pinch because of pain at the base of the thumb.

ROENTGENOGRAPHIC FINDINGS

Roentgenograms of the fractures reported in the literature indicate that most of these were simple avulsion injuries, especially the isolated fractures. The grossly comminuted fractures caused by penetrating wounds or severe direct trauma presented no serious problem in roentgenographic diagnosis. The fractures in the series reported here were all of the vertical type, with consequent dislocation of the first metacarpal associated with displacement of the radial fragment.

Approximately 20 per cent of the fractures that were reported with adequate reproductions of the roentgenograms or adequate descriptions of the fracture were vertical.

A major cause of error in the diagnosis of fractures of the greater multangular is inadequate roentgenograms. Routine anteroposterior views do not delineate the greater multangular adequately, for it is obscured by the lesser multangular and the base of the second metacarpal. In the postero-anterior views it is likewise obscured by the base of the second metacarpal. A true lateral projection demonstrates the radial three-fourths of the greater multangular but the ulnar one-fourth is obscured by the hook of the hamate. The most satisfactory projection is an oblique view, made with the ulnar border of the hand resting on the cassette and the forearm in 20 degrees of pronation. The entire horizontal diameter of the multangular with its articulation with the second metacarpal and lesser multangular is then visualized. A carpal-tunnel view shows the superior articular surface of the greater multangular, but with poor definition. No satisfactory projection has been evolved to demonstrate the volar hook, or tubercle, of the bone.

Five patients with fracture of the greater multangular were treated by us during the past six years.

CASE REPORTS

Case 1. An eighteen-year-old white girl was thrown from the car, in which she was a passenger, during an automobile accident. She could recall no specific injury to the left arm but noted immediate pain and discomfort in the left wrist. She was seen by a physician immediately after the accident and routine anteroposterior and lateral roentgenograms of the wrist were obtained. However, because of inadequate roentgenograms no definite diagnosis was made and the patient was permitted to use the wrist within the limits of discomfort. Because of continued discomfort, two weeks later additional roentgenograms of the wrist were made in multiple projections. These disclosed a longitudinal fracture of the greater multangular with displacement of the lateral fragment and the first metacarpal (Fig. 1-A). The patient said that she had discomfort only when the wrist was at the extremes of motion. Her principal complaint was weakness of the thumb and discomfort on attempted pinching and grasping. The normal contour of the hand was well preserved and there was no gross deformity. Open reduction was performed with the patient under brachial-block anesthesia; the fragments were reduced and maintained in position by one Kirschner wire inserted through the fragments (Fig. 1-B). Ten days after surgery the postoperative pressure dressing was removed and a short arm cast was applied, which immobilized the thumb in a position of abduction and opposition. Eight weeks after operation external immobilization was discontinued and the patient was permitted limited activity of the hand. Three months after operation the Kirschner wire was removed and full motion was permitted. One year later there was full active motion of the thumb. There was normal pinch and grasp and full opposition. The patient engaged in all sports and was a particularly avid horsewoman. On re-evaluation two years later, the hand was found to be asymptomatic with full motion of the wrist and fingers. Roentgenograms then revealed the fracture to be healed in good position and a normal joint space maintained (Fig. 1-C).

Case 2. A forty-year-old white machinist sustained a direct blow on the radiodorsal aspect of the right wrist from the unsecured bar of a punch press. He noted immediate pain and limitation of motion of the thumb. Shortly after the injury swelling of the hand appeared and he reported to the plant dispensary where routine anteroposterior and lateral roentgenograms of the wrist were made and reported to be negative. An elastic bandage was applied and the patient was permitted to return to work. He continued to have discomfort and moderate limitation of motion of the wrist with pain on attempted pinch and grasp, as well as a sensation of weakness of the thumb. Repeat roentgenograms made on November 21, 1956, revealed a longitudinal fracture of the greater multangular with an associated chip fracture of the base of the second metacarpal. An old fracture of the ulnar styloid process was also noted (Figs. 2-A and 2-B). Open reduction of the fracture was performed on November 24, 1956, through a two-inch horizontal incision at the base of the thumb. The greater multangular was found to be fractured into two segments of equal size. The radial fragment was displaced proximally and the first metacarpal was subluxated in association with this radial fragment. The fracture was reduced without undue difficulty and two transfixion pins were placed across the fracture to maintain the reduction. The wrist and thumb were

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Fracture of the greater multangular with proximal displacement of the radial fragments and subluxation of the first metacarpal. Despite roentgenograms made at the time of injury, the proper diagnosis was missed until two weeks after the fracture had occurred.

Fig. 1-B: An anteroposterior view of the greater multangular, obtained by an oblique projection, reveals an anatomical reduction, maintained with a single subcutaneous Kirschner wire. A plaster cast was applied, with the thumb held in abduction.

immobilized in a pressure dressing for ten days after surgery. The dressing was then removed and a short arm cast was applied, with the thumb included. The cast was changed after four weeks, when the Kirschner wires were removed. Nine weeks after operation the cast was bivalved and reapplied as a splint, which was removed four times daily for general exercise of the wrist and thumb. One month later all splinting was discontinued and the patient began to use the hand for light activity. One year after injury he was asymptomatic and stated that he was working full time as a machinist; examination revealed full active motion of the right wrist and thumb, as compared with the left. On re-evaluation three years after injury the patient still had no specific discomfort in the hand, was working as a setup machinist, and had full motion of the thumb and wrist. Roentgenograms revealed the fracture to be healed in normal position with the articular surfaces maintained (Fig. 2-C).

CASE 3. A white dairyman, twenty-two years old, sustained a direct blow on the radiodorsal aspect of the wrist when a farm machine toppled from the blocks on which it was resting. There was immediate pain and shortly thereafter swelling of the wrist and hand appeared together with a feeling of weakness of the thumb. The patient continued to work but on the following day was unable to pinch or grasp effectively. Roentgenograms revealed a longitudinal fracture of the greater multangular with the first metacarpal displaced proximally, together with the radial fragment. On April 3, 1954, open reduction and internal fixation with a subcutaneous Kirschner wire was performed. The hand was immobilized in a pressure dressing for ten days. A forearm cast, which incorporated the thumb, was worn until June 6, 1954, at which time roentgenograms revealed healing of the fracture. Thereafter, a removable splint was used and the patient did active exercises. All immobilization was discontinued on the patient's own initiative three weeks after active motion had been instituted. On September 26, 1954, motion of the thumb and wrist was comparable with that in the unaffected extremity and the Kirschner wire was removed. The patient was subsequently lost to follow-up.

CASE 4. A Negro construction worker, sixty-seven years old, sustained a direct blow on the radiodorsal aspect of his left hand when a concrete piling crumpled and fell. The injury occurred

FIG. 1-C

Three years after injury an oblique roentgenogram shows the fracture to be well healed. There is no sclerosis or other evidence of traumatic arthritis and the joint space is well maintained. The patient had full active motion of the thumb.

on May 23, 1959; the patient reported for treatment on May 25, 1959, because of increasing swelling of the hand and pain in the wrist and thumb. Examination of the left upper extremity revealed an abrasion over the radiodorsal aspect of the hand with gross swelling of the entire hand and wrist. Motions of the thumb and wrist were limited and painful. Roentgenograms revealed an oblique fracture of the proximal phalanx of the thumb and a longitudinal fracture of the greater multangular. Because of the contaminated abrasion, open reduction of the fracture of the greater multangular was deferred, and the hand and thumb were immobilized in a plaster splint. On June 4, 1959, open reduction of the greater multangular was performed, and the fracture fragments were fixed in position with a subcutaneous Kirschner wire. The pressure dressing applied at the end of the operation was removed on June 23, 1959, and a short arm cast applied with the thumb in the water-glass position. The cast was bivalved on July 2, 1959, at which time roentgenograms revealed apparent healing of the fracture. Thereafter, the bivalved cast was removed periodically for active motion of the wrist and thumb. On July 28, 1959, the Kirschner wire was removed. When the patient was re-examined on September 28, 1959, he had a full range of active motion of the thumb and wrist and had returned to his usual occupation. Roentgenograms revealed that the fracture was healed with the fragments in good position.

CASE 5. A fifteen-year-old boy fell from a height of about six feet and struck his right hand against a concrete wall on May 3, 1957. He had moderate discomfort in the hand and thumb immediately and, shortly after the injury, noted swelling of the hand which became progressively more severe. On the day after injury, examination revealed moderate swelling of the hand with limitation of motion of the wrist and digits and discomfort over the radial aspect of the wrist. All motions of the thumb were limited by pain and there was weakness of pinch and grasp. Roentgenograms revealed a vertical fracture of the greater multangular with proximal displacement of the radial fragment and subluxation of the first metacarpal. Open reduction was performed forty-eight hours after examination; the fracture fragments were reduced and maintained by a Kirschner wire. A pressure dressing was worn for two weeks and then was replaced by a short arm cast which main-

FIG. 2-A

FIG. 2-B

Figs. 2-A and 2-B: Case 2. Fracture of the greater multangular, the result of a direct blow. The radial fragment is displaced proximally and the first metacarpal is subluxated, as manifested by the fact that its base lies below that of the second metacarpal. The nature of this injury was not recognized on the initial roentgenograms.

FIG. 2-C

Three years after fracture. The first metacarpocarpal joint is well preserved and there is no sclerosis or other evidence of traumatic arthritis. The relationship of the multangular to the scaphoid is within normal limits.

tained the thumb in abduction. Eight weeks after operation the cast was bivalved and used as a splint. Limited motion of the hand from the splint was begun at that time. The Kirschner wire was removed and full motion was permitted ten weeks after operation. When the patient was last seen, six months after surgery, he had full motion of the wrist and thumb with strong pinch and grasp.

TREATMENT

The five patients reported here had vertical displaced fractures which were treated by open reduction. The only alternative mode of treatment which could

effect and maintain reduction would appear to be constant traction to the abducted thumb until healing of the fracture has occurred. Because of the importance of the first metacarpocarpal joint to the function of the thumb and hand it is believed that anatomical reduction and internal fixation are indicated to provide the earliest possible restoration of motion of the thumb with the least possibility of subsequent traumatic arthritis.

The fracture is approached through a two-inch horizontal incision over the radial aspect of the wrist and just proximal to the base of the first metacarpal. The cutaneous branch of the radial nerve to the thumb lies within the scope of this incision and is retracted ulnarward with its loose subcutaneous tissue. Care should be taken to identify the nerve. If it is severed an annoying degree of hypesthesia will be present over the radial aspect of the thumb. After identification the nerve may be mobilized easily but retraction should be gentle lest there be local discomfort at the area of the incision and hypesthesia over the radial aspect of the thumb after operation. The extensor pollicis brevis is identified and retracted volarward, together with the abductor pollicis longus. To permit more adequate exposure with less vigorous retraction, the dorsal carpal ligament is incised vertically for from one-quarter to one-half of an inch parallel with the tendons. The tendon of the extensor pollicis longus is retracted ulnarward. The radial artery, at the base of the wound directly upon the capsule of the first carpometacarpal joint, is gently retracted ulnarward. The capsule is opened by a transverse incision exposing the joint. When there is subluxation of the first metacarpal, its base obscures the fracture surface of the ulnar fragment. With traction on the thumb the fracture is readily exposed. The fracture faces are cleared of all clot and granulation tissue, and all fragments of bone or cartilage are removed from the joint. A Kirschner wire is then driven into the radial fragment and used as a handle to manipulate the radial fragment into anatomical position. While the surgeon maintains this position, an assistant drills a second wire through the two fragments; the initial wire may then be driven into the ulnar fragment as well. The wires are clipped to lie just beneath the skin and the wound is closed in layers. The hand is immobilized in a pressure dressing for ten days. A short arm cast is then applied with the abducted, slightly flexed thumb included; this is worn for an additional six weeks. All the fractures treated by this method were well healed at eight weeks, but partial splinting was continued until full motion of the thumb was restored, usually by the end of the third postoperative month.

DISCUSSION

This small series of fractures of the greater multangular treated by open reduction and internal fixation is reported because of the importance of the first metacarpocarpal articulation to the hand and the preliminary good results that have been obtained. This procedure would appear to be the treatment of choice to ensure anatomical reduction and thus to minimize future degenerative changes and to maintain the stability of the first metacarpocarpal joint. In addition, open reduction and internal fixation permit relatively early mobilization of the thumb with minimum danger of displacement of the fracture fragments. Early motion should reduce the risk of contractures of the capsule and thumb web. All five patients in this series regained full motion of the thumb.

Of the five cases reported here, three were isolated fractures of the greater multangular and two were fractures of this bone, associated with an undisplaced second metacarpal in one and an undisplaced oblique fracture of the proximal phalanx of the thumb in the other. In three of these five patients there was direct

trauma to the radiodorsal aspect of the hand. In one, the exact mechanism of trauma was not known, and in the other the fracture resulted from a direct blow combined with a fall from a height. The typical isolated fracture of the greater multangular is a vertical crack through the mid-portion of the bone, with some proximal displacement of the radial fragment. Since the first metacarpal articulates primarily with this fragment, it is displaced proximally from its normal position.

Only two of the five patients reported have been followed for more than six months; both had completely satisfactory results three years after injury. The other three patients were asymptomatic four, five, and six months, respectively, after operation; two of these patients have been lost to follow-up. This report must therefore be considered preliminary.

CONCLUSIONS

From a survey of the literature it would appear that fractures of the greater multangular are less rare than was anticipated. They usually occur in association with other fractures about the wrist.

Analysis of the fractures reported in the literature disclosed no agreement as to the treatment of choice.

Longitudinal fractures of the greater multangular, in our experience and from study of available published roentgenograms, are unstable and are accompanied by subluxation of the first metacarpal.

Since clinical findings are relatively minimum, accurate diagnosis is dependent on adequate roentgenograms. An oblique projection is necessary to obtain a true anteroposterior view of the greater multangular.

To achieve a stable, anatomical reduction of the fracture and assure restoration of the articular surfaces of the first carpometacarpal joint, open reduction and internal fixation are recommended.

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(Continued on page 1190)

Into-Talus Transposition of Tendons for Correction of Paralytic Valgus Foot after Poliomyelitis in Children*

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Paralytic valgus deformity of the foot of a dynamic character is caused by muscle imbalance between the invertors and evertors of the foot. The characteristic feature of this deformity is the medial and downward displacement of the talus with reference to the rest of the foot. This is initiated by the lateral displacement of the calcaneus and the fore part of the foot and is caused by the unopposed action of evertor muscles. In such an equinovalgus deformity the talus becomes markedly displaced downward until it becomes completely vertical, as in a fully developed rocker-bottom deformity.

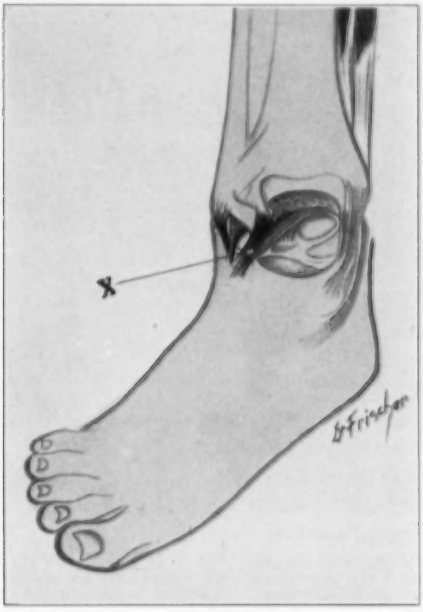

FIG. 1

The anterolateral portion of the talocalcaneal interosseous ligament (*X*) and the shortened ligaments on the lateral aspect of the ankle joint in a paralytic foot with valgus deformity are shown in black. (Adapted from "Praktische Anatomie: Ein Lehr-und Hilfsbuch der Anatomischen Grundlagen Ärztlichen Handelns." Vol. 1: Bein und Statik, p. 349, fig. 286. By T. von Lanz and W. Wachsmuth. Berlin, Julius Springer, 1938.)

This displacement or rotation of the talus leads to restriction of movement in both the talocalcaneonavicular and the ankle joints. The tough talocalcaneal interosseous ligament, as well as the capsule and the ligaments situated on the outer, posterior, and anterior aspects of the talus and calcaneus, become shortened

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and practically preclude manipulative reduction of the dislocation (Fig. 1). After the deformity is established in a growing child, the structural changes that develop insidiously in the skeleton of the foot may prove to be irreversible.

KINESIOLOGICAL CONSIDERATIONS

The talus, which is the mechanical keystone of the foot, has no muscles attached to it. Therefore, under normal circumstances, its position and movements

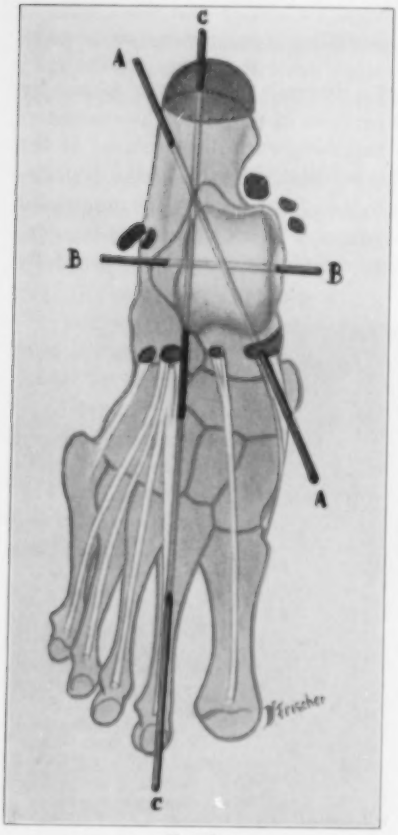

FIG. 2

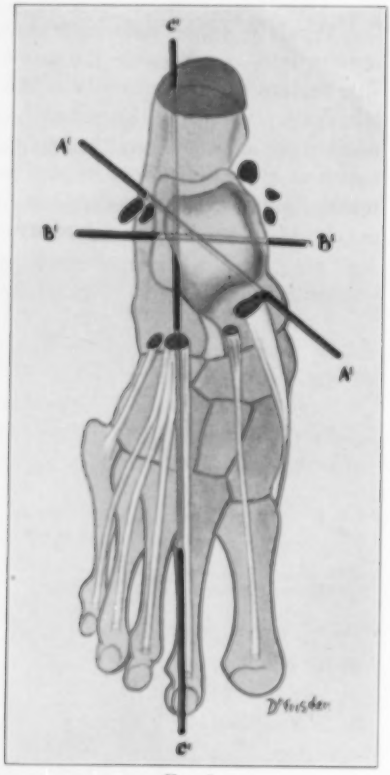

FIG. 3

Fig. 2: The nine long muscles of the leg which control the interdependent movements of the ankle, Chopart's joint, and the talocalcaneonavicular joints are shown with their relationships to the axes around which these movements take place under normal conditions.

The axis of the talocalcaneonavicular joint (*A-A*) passes through the tendon of the tibialis anterior muscle; hence, the tibialis anterior is a neutral muscle so far as eversion-inversion movements are concerned. (Reproduced from "Praktische Anatomie: Ein Lehr-und Hilfsbuch der Anatomischen Grundlagen Ärztlichen Handelns." Vol. 1: Bein und Statik, p. 352, fig. 289. By T. von Lanz and W. Wachsmuth. Berlin, Julius Springer, 1938.)

Fig. 3: In a foot with valgus deformity in which the characteristic medial displacement of the talus takes place, the tendon of the tibialis anterior runs lateral to the axis of the talocalcaneonavicular joint (A^1-A^1); under these circumstances, the tibialis anterior becomes an evertor of the foot. (Adapted from "Praktische Anatomie: Ein Lehr-und Hilfsbuch der Anatomischen Grundlagen Ärztlichen Handelns." Vol. 1: Bein und Statik, p. 352, fig. 289. By T. von Lanz and W. Wachsmuth. Berlin, Julius Springer, 1938.)

are determined by the nine long muscles of the leg that control the interdependent movements in the ankle and in subtalar joints and the joints in the middle part of the foot.

The invertors of the foot—the tibialis posterior, flexor digitorum longus,

and flexor hallucis longus—run medially to the oblique axis of rotation of the talocalcaneonavicular joint (Fig. 2, *A-A*) and insert into the navicular with fibrous expansions to the three cuneiform bones and to the bases of the second, third, and fourth metatarsals and into the toes (distal to Chopart's joint). Their actions therefore affect both the subtalar and the talonavicular joints. The triceps surae is a very powerful supinator since the force of its contraction is exerted medial to the oblique axis of rotation of the talocalcaneonavicular joints. However, since it inserts into the calcaneus, it acts as a supinator of the subtalar joint only.

The evertors of the foot are the peroneus longus, brevis, and tertius, the extensor digitorum longus, and the extensor hallucis longus. The direction of force developed by their contractions runs lateral to the oblique axis of the talocalcaneonavicular joints (Fig. 2). The combined strength of these muscles is approximately balanced by the invertors of the foot, excluding the triceps surae.

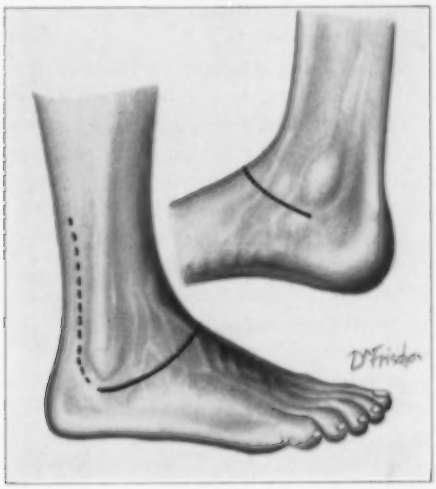

FIG. 4

The U-incision and its lateral prolongation utilized in the transplantation of the peroneal muscles.

The tendon of the tibialis anterior passes anterior to the transverse axis of the ankle joint (Fig. 2, *B-B*) and medial to the longitudinal axis of Chopart's joint and the subtalar joint (Fig. 2, *C-C*). The tibialis anterior is therefore a dorsiflexor and a supinator of the fore part of the foot.

In the normal foot the tibialis anterior passes through the axis of the talocalcaneonavicular joint (Fig. 2, *A-A*); it is therefore a neutral muscle in so far as pure eversion and inversion of a normal foot are concerned.

When the so-called true invertors of the foot—the tibialis posterior, flexor hallucis longus, and flexor digitorum longus—become paralyzed or paretic and the unopposed or insufficiently opposed action of the evertors causes the typical deformity with medial and downward displacement of the talus, the oblique axis of the talocalcaneonavicular joints also changes its course and becomes more transverse (Fig. 3, A^1-A^1), with the result that the tendon of the tibialis anterior comes to lie lateral to it. In this event the tibialis anterior actually functions as an evertor of the foot, but this muscle is almost always paralyzed when the tibialis posterior is involved [8]. It thus seems obvious that any muscle that is transferred anterior to the ankle joint to restore the action of the tibialis anterior will only accentuate the deformity—no matter where on the fore part of the foot it is attached—as long as its new attachment is distal to Chopart's joint and the

paralyzed true invertors are not replaced concurrently to restore the delicate evertor-invertor balance. It seems reasonable to suspect that many of the disappointing results following tendon transplantation have been due to the fact that transplantations of muscles to the fore part of the foot have been performed without regard to whether the valgus deformity was caused by paralysis of both the true invertors and the tibialis anterior or by paralysis of the tibialis anterior alone (Table I, Cases 2, 5, 17, and 19).

Equinovalgus deformity caused by paralysis of the anterior tibial alone is easily, and usually permanently, corrected by one of the routine procedures, such as transfer of the peroneus longus to the tibialis anterior, according to Mayer's method; a Jones suspension; or transfer of the extensor digitorum longus to either the medial border or the middle of the foot. The reason for the success of these procedures under these circumstances is that no serious displacement of the talus has occurred in these feet because the balance between true invertors and evertors has remained practically undisturbed.

Arthrodesis of the tarsal joints is a very useful operation for the correction of deformities of the foot. However, it has been proved that if arthrodesis is not accompanied by restoration of muscle balance, recurrence of the deformity may occur [2]. Moreover, the important function of the tarsal joints—which can be compared with the function of the shock absorbers and springs of an automobile—should not be underestimated. As Steindler pointed out: "A great many of the operative failures arise from the fact that the secondary effect of the arthrodesis on neighboring joints is not taken into consideration".

For these reasons when operating on a small child, I am reluctant to eliminate the subtalar joint permanently, as suggested by Grice.

In some situations I prefer moderate valgus deformity of the foot with some painless motion in the tarsal joints to a well formed but stiff foot.

Obviously, the restoration of muscle balance is the *sine qua non* for the correct treatment of any dynamic deformity. It is difficult, however, to achieve muscle balance in the foot when the true invertors are paralyzed.

It occurred to me that a direct, dynamic control of the unruly talus, the mechanical keystone of the foot, might offer a solution to this difficult problem. Consequently, the into-talus operation was devised early in 1953.

THE OPERATION

A U-shaped incision is made across the proximal third of the dorsum of the foot, starting one fingerbreadth below the medial malleolus and following the skin creases. If the peroneal muscles are to be transplanted, the U-incision is prolonged by continuing it behind the lateral malleolus and upward along the lateral aspect of the distal two-thirds of the leg (Fig. 4). Through this prolonged U-incision both peroneal muscles can be exposed and, if necessary, the Achilles tendon can be lengthened. If lengthening of the Achilles tendon is indicated in a situation in which the short U-incision is used, then a separate incision over the Achilles tendon is necessary. Through the U-incision the tendons of all the dorsiflexors and evertors of the foot are exposed; those chosen for transplantation into the talus are divided as far distally as possible. After their division, the tendons of the extensor digitorum longus and peroneus tertius are sutured together into one conjoined tendon. All the tendons to be transferred are dissected proximally to above the level of the ankle joint to eliminate kinking when they are moved to the medial or lateral aspects of the talus for transplantation. For the same reason, the tendons of the peroneus longus and brevis muscles are dissected further proximally into the leg.

After preparation of the tendons chosen for transplantation, the talus is mobilized by a radical dissection. The capsule of the talonavicular joint is divided around the head and neck of the talus, the ligaments on the lateral aspect of the talus are cut, and the talocalcaneal interosseous ligament (the toughest structure of them all and the one mainly responsible for fixation of the dislocation of the subtalar joint in pronation) is divided completely.

A transverse tunnel to receive the transplanted tendons is made in the neck of the talus with a spike. With this instrument inserted through the neck of the talus, the mobilization of the talus is facilitated by using this instrument as a handle to lift this bone off the calcaneus to expose the interosseous ligament and

FIG. 5

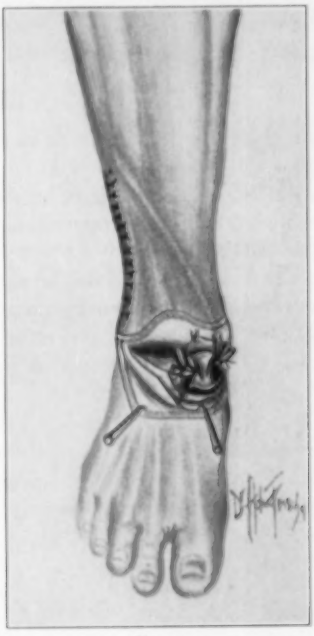

FIG. 6

Fig. 5: The displaced talus has been mobilized and is ready for reduction. The tendon of the peroneus longus and the tendons of the extensor digitorum longus and peroneus tertius have been prepared with guiding sutures for transposition into the tunnel through the neck of the talus, into which a probe has been placed.

Fig. 6: After reduction of the talus and insertion of the tendons into the tunnel from both sides, the tendons are sutured under tension to themselves. The talus is now lifted and the longitudinal arch of the foot is restored.

make possible its complete division. While dividing the capsule of the talonavicular joint, the soft tissues, which contain the dorsalis pedis artery and nerve and are situated between the tendons of the tibialis anterior and extensor hallucis longus, are lifted off the capsule with a hook to protect the neurovascular bundle.

If necessary, the Achilles tendon is divided in a Z-fashion but it should not be reconstructed until after fixation of the tendons into the talus is completed, since only then can the optimum length be estimated with reasonable accuracy.

After dissection, the talus can usually be reduced with ease by pushing its head laterally and inverting the calcaneus at the same time. The prepared tendons are then introduced from both sides into the tunnel in the neck of the talus by using guiding sutures (Fig. 5). After the tendons have been threaded through the tunnel, they are pulled upward and sutured to themselves under appropriate

tension (Fig. 6). In that way the talus is lifted upward and laterally and improvement in the longitudinal arch of the foot is seen immediately. With the foot in the corrected position the Achilles tendon is reconstructed and the medial capsule of the subtalar joint is repaired, plicating it*, if need be, to provide ligamentous support for the head of the talus.

If both the peroneus longus and the peroneus brevis are used for transplantation they are transferred subcutaneously to the horizontal limb of the U-incision, the peroneus longus going to the medial and the peroneus brevis to the lateral aspect of the talus. If only one of these muscles is transplanted its tendon is split longitudinally and each half is then introduced into the tunnel from opposite sides of the talus. They are then sutured together under tension, in the usual way.

The wound is closed in layers and a below-the-knee cast is then applied. This is worn for six weeks; later, a brace is worn for a minimum of six months.

CLINICAL MATERIAL

This paper is based on the analysis of the results of twenty-six operations performed on twenty-four children during the years between July 1953 and December 1956. The results of seven reoperations (two in one patient, Case 20) are also included. Sixteen operations were performed on the left foot and ten on the right foot.

At the onset of paralysis the ages of the patients ranged from three months to two years and three months, an average age of one year and two months.

At operation, the youngest child was one year and eleven months old and the oldest was nine years; the average age was five years and two months.

RESULTS

The preliminary results of these twenty-six operations are summarized in Table I. These results were classified according to both the anatomical and the functional results found at follow-up examination. The period of follow-up ranged from one year and three months to five years and eight months, an average of two years and eight months.

Anatomical Results

The anatomical results (Column 11) were classified according to the change in the angle formed by the long axis of the talus with the plantar surface of the foot (the taloplantar angle), as measured on lateral roentgenograms made before operation (degrees in parentheses) and at follow-up examination (degrees outside parentheses). Whenever possible, the angles formed by the longitudinal axes of the talus and calcaneus (the talocalcaneal angle), as measured on dorsoplantar roentgenograms made before operation and at follow-up, were tabulated in the same fashion and follow the degrees for the taloplantar angle. The talocalcaneal angle is a rough measure of the degree of medial displacement of the head of the talus with reference to the calcaneus.

Also considered in the assessment of anatomical results was the difference in the appearance of the foot, as measured by photographs made of the patient during weight-bearing, both before operation and at follow-up. The final assessment in the grading was the stability of the foot at follow-up examination.

The anatomical results were graded as *very good* in sixteen feet (Cases 1, 2, 3, 7, 8, 11, 13, 14, 16, 19, 21, 24, and both feet of Cases 5 and 10). All these feet were stable and their deformities were corrected, as determined by clinical exami-

* To avoid overcorrection reconstruction of the capsule on the medial aspect of the subtalar joint should be done only in selected cases.

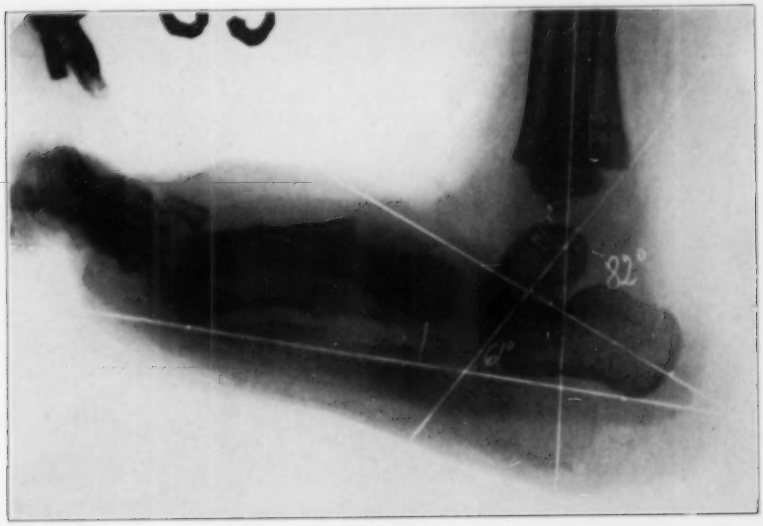

FIG. 7-A

Case 1, a boy, two years and nine months old. Preoperative lateral roentgenogram of the right foot shows severe valgus deformity with a vertical talus. The taloplantar angle is 61 degrees.

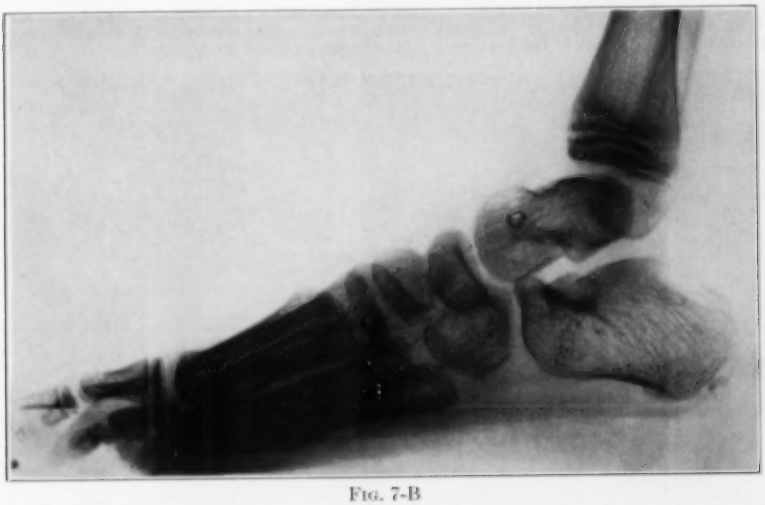

FIG. 7-B

Lateral roentgenogram of the right foot five years and eight months after Fig. 7-A was made. The tibialis anterior had been transplanted at the first operation with only partial correction (the taloplantar angle was 43 degrees). Eighteen months later the extensor digitorum longus and peroneus tertius were transplanted. At follow-up, five years and eight months after the first operation, the relationship of the tarsal bones was normal and the taloplantar angle was 15 degrees.

nation. The taloplantar or the talocalcaneal or both these angles showed a minimum correction of 11 and 9 degrees, respectively (Case 13), and a maximum correction of 63 degrees (Case 5, right foot).

In Cases 15 and 17, slight overcorrection was noted at follow-up examination. Accordingly, the results in these feet were graded as *good*, even though the roentgenographic appearance was very satisfactory. It was apparent, in these cases, that the taloplantar and talocalcaneal angles may be misleading since a varus adductus deformity may develop distal to Chopart's joint.

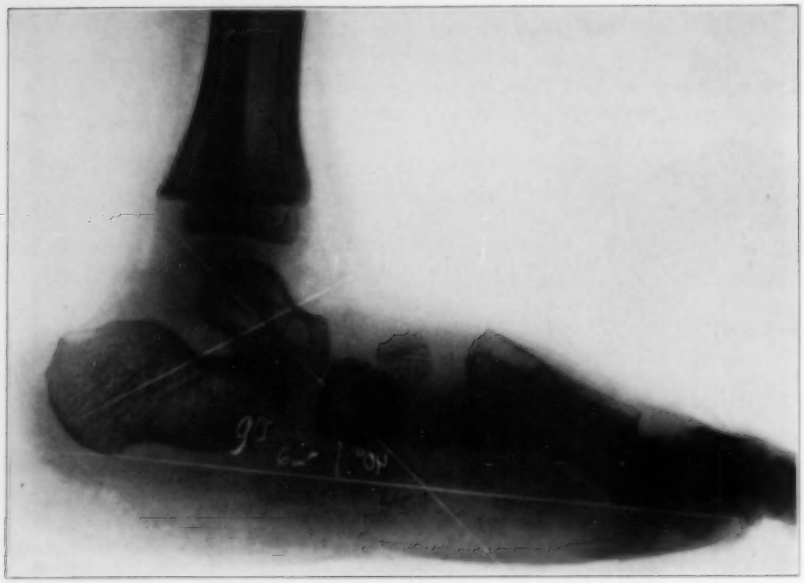

FIG. 8-A

Case 3, a boy, four years old. A lateral roentgenogram made before operation shows equinus deformity of the back part of the foot, with a taloplantar angle of 40 degrees.

FIG. 8-B

Lateral roentgenogram made of the left foot at follow-up, three years and seven months after transplantation of the extensor digitorum longus and peroneus tertius to the neck of the talus, shows normal relationship of the tarsal bones with a taloplantar angle of 14 degrees.

The results in five cases (4, 9, 12, 22, and 23) were classified as *fair* because of some overcorrection (Case 4) or only partial correction (Cases 9, 12, and 22). In Case 23, the result by roentgenogram was rated as *bad*, but at clinical examination there was definite improvement in the shape of the foot, as verified by photographs. Accordingly, this patient was rated as having a *fair* anatomical result.

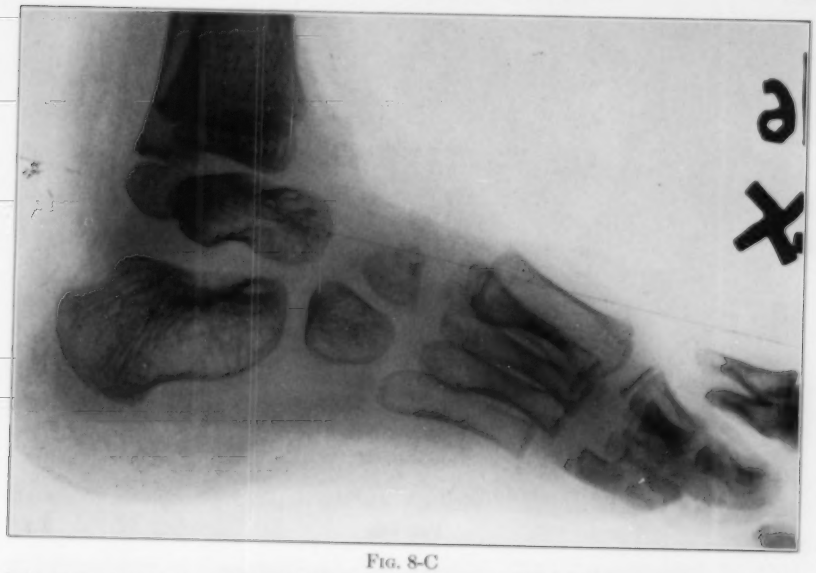

FIG. 8-C

Lateral roentgenogram, made at the same time as Fig. 8-B, of the left foot during active dorsiflexion against resistance applied to the fore part of the foot. Note the supination of the foot and the elevation of the head and neck of the talus due to the action of the transplants.

FIG. 8-D

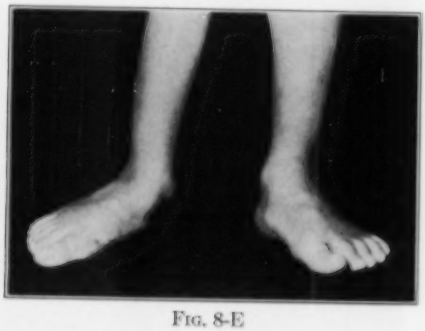

FIG. 8-E

Fig. 8-D: Preoperative appearance of the left foot during weight-bearing.
Fig. 8-E: Appearance during weight-bearing at follow-up (three years and seven months after operation). Note the correction of the valgus deformity.

There were three *bad* results. Originally, in all of these feet there had been a calcaneovalgus deformity and all posterior muscles had been transplanted (all-posteriors procedure) prior to the into-talus operation.

In the patient in Case 6, the all-posteriors transplantation was followed by an infection that caused such massive scarring of the Achilles tendon that lengthening of this tendon during the into-talus transplantation was impossible. Hence, the vertical talus could not be corrected satisfactorily.

In the patient in Case 18, during a previous all-posteriors operation one-half of the extensor digitorum longus tendon had been transferred into the Achilles tendon and the other half had been inserted into the middle part of the foot. In a subsequent procedure, the anterior half of the common extensor tendon was transferred into the talus, together with the extensor hallucis longus for correction of the valgus deformity. These procedures were poorly conceived; there were

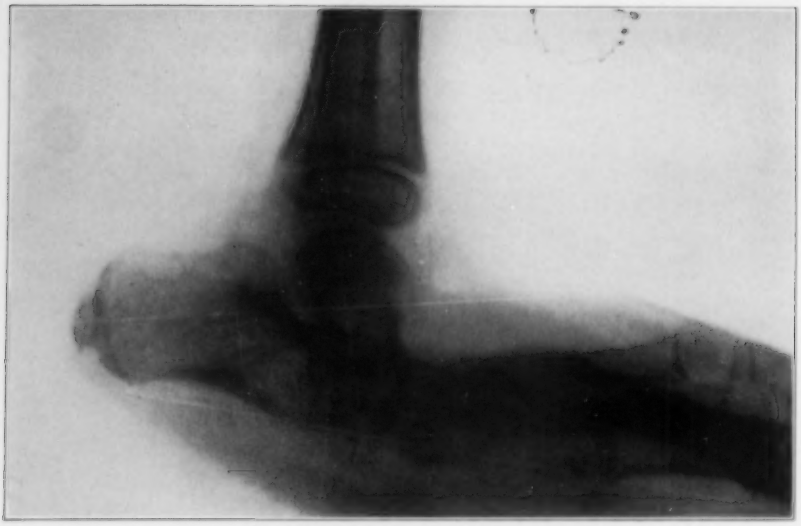

FIG. 9-A

FIG. 9-B

Figs. 9-A and 9-B: Case 5, a girl, six years old. Lateral roentgenograms of both feet before operation show severe bilateral rocker-bottom deformities. The taloplantar angle of the right foot is 83 degrees and of the left, 72 degrees.

multiple tendon transplantations in which one muscle was expected to perform as both dorsiflexor and plantar flexor.

In the patient in Case 20, valgus was the principal deformity originally. Therefore, the into-talus transplantation should have been the first procedure. After transplantation of all the muscles posteriorly, first an equinus deformity developed, and then a varus deformity, which was probably caused by the combined action of the short medial muscles of the foot and of the extensor hallucis longus. The latter had been transferred to the neck of the first metatarsal simultaneously with the into-talus transplantation.

FIG. 9-C

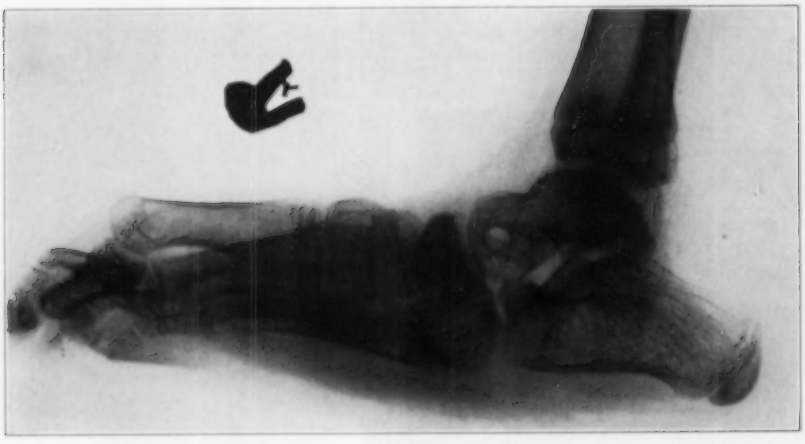

FIG. 9-D

Figs. 9-C and 9-D: Lateral roentgenograms of both feet at follow-up, approximately three and a half years after surgery. There has been considerable improvement of the deformity. The talo-plantar angle of the right foot is now 20 degrees and of the left, 18 degrees.

The deforming action of the short muscles of the foot causing adduction and varus of the front part of the foot was also observed in other patients. Recently, during the into-talus transplantation and through the same U-incision, I have been denervating these muscles in some patients. My experience with this additional procedure is too limited and too recent to permit any assessment of the results.

Functional Results

The functional results are recorded in Column 12 of Table I. Here the gradings are based on the strength of dorsiflexion at follow-up (as compared with pre-operative strength), on the range of passive motion at the ankle and talocalcaneonavicular joints, on gait (motion pictures were made of some children before operation), and on the need for a brace.

FIG. 9-E

FIG. 9-F

Fig. 9-E: Preoperative appearance of both feet during weight-bearing.
Fig. 9-F: Appearance during weight-bearing at follow-up (approximately three and a half years after surgery).

FIG. 10-A

FIG. 10-B

Figs. 10-A and 10-B: Case 8, a boy three years and one month old. Dorsoplantar and lateral roentgenograms of the left foot before operation show moderate equinus deformity of the talus (taloplantar angle, 35 degrees) but marked medial displacement of the talus (talocalcaneal angle, 60 degrees). This was predominantly a valgus deformity.

A rating of *3* means that the child is able to dorsiflex the foot actively against gravity to a right angle. Comparison of these ratings with those for muscle power before operation (Column 5) reveals a reduction of strength of dorsiflexion in many patients. The marked shortening of the lever arm caused by implantation of the tendons into the neck of the talus close to the transverse axis of rotation of the ankle joint was primarily responsible for this loss of power. In patients in whom only the extensor digitorum longus muscle was implanted into the talus, or still better only a part of it, the power of dorsiflexion often remained at about *3* (Cases 2, 3, and 7). Still stronger dorsiflexion was obtained in some feet in which all the muscles anterior to the ankle were left undisturbed and either the

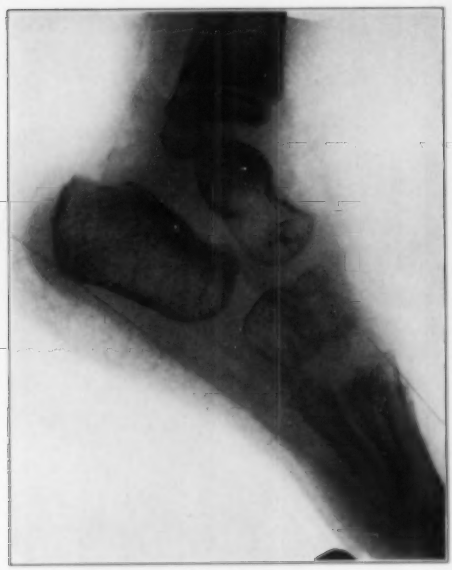

FIG. 10-C

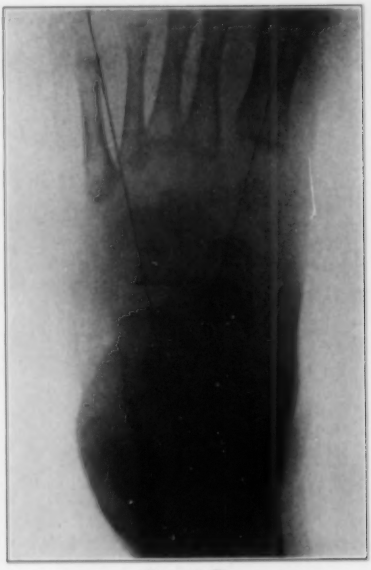

FIG. 10-D

Figs. 10-C and 10-D: Dorsoplantar and lateral roentgenograms of the left foot at follow-up, three years and two months after transplantation of the peroneus longus into the neck of the talus, show good correction. The taloplantar angle is 12 degrees and the talocalcaneal angle, 28 degrees.

FIG. 10-E

FIG. 10-F

Fig. 10-E: Preoperative appearance of the feet during weight-bearing.
Fig. 10-F: Appearance during weight-bearing at follow-up (three years and two months after operation). Note the improvement in the shape of the left foot.

peroneus longus alone or both peronei were transferred into the talus (Cases 8, 21, and both feet of Case 10).

Although weakened by transfer, the transplanted muscles still seemed to exert a corrective force on the talus, as indicated by the roentgenograms of Case 3 (Figs. 8-A, 8-B, and 8-C). In Figure 8-C, a lateral roentgenogram made during active dorsiflexion against resistance applied to the fore part of the foot, the foot is supinated and the talus lifted (for comparison see Figure 8-B). This roentgenogram shows the positions of the talus and other bones of the foot while at rest.

In only six patients were the functional results classified as *very good* (Cases 2, 3, 8, right foot of 10, 21, and 22). These children could dorsiflex the foot actively against gravity to above 90 degrees and had a full range of passive motion in the ankle and talocalcaneonavicular joints. The gait was normal in these patients or it improved (some patients were paraplegic).

In eight patients the functional results were classified as *good* (Cases 1, 4,

FIG. 11-A

FIG. 11-B

Fig. 11-A: Case 20, a girl, seven years old. Dorsoplantar roentgenogram of the left foot five months after transplantation of all posterior muscles into the Achilles tendon to prevent calcaneus deformity (first operation). The talocalcaneal angle is 40 degrees.

Fig. 11-B: Dorsoplantar roentgenogram of the left foot after second operation, transplantation of the extensor digitorum and peroneus tertius into the talus; a Jones suspension was done at the same time. Note overcorrection and abduction of the fore part of the foot.

FIG. 11-C

FIG. 11-D

Fig. 11-C: Preoperative appearance of the feet during weight-bearing.

Fig. 11-D: Appearance during weight-bearing twenty-two months after the second operation, into-talus transplantation combined with a Jones suspension. The result was classified as *bad*. Consequently, fourteen months after the second procedure and sixteen months after the reoperation (extensor hallucis longus into the talus), arthrodesis was performed.

7, 9, left foot of 10, 11, 14, and 23). The children in this category could actively dorsiflex the foot to 90 degrees or slightly less (Case 1). Motion at the talocalcaneonavicular joints was preserved or only slightly limited. The gait was nearly normal in these children.

In nine patients the functional results were classified as *fair* (both feet of

Case 5 and Cases 12, 13, 15, 16, 17, 19, and 20). Dorsiflexion was weak, the Achilles tendon was usually short, and the children had a typical drop-foot gait, necessitating a dorsiflexion brace in some instances.

In the remaining three patients (Cases 6, 18, and 24) the functional results were classified as *bad*. There was no active dorsiflexion and braces were needed.

Combined Classification

A combined classification (Column 13, Table I) is based on both the anatomical and the functional results.

In five patients, the combined results were classified as *very good* (Cases 2, 3, 8, right foot of 10, and 21), since both the shape and the function of the feet were essentially normal.

In nine patients the combined results were classified as *good* (both feet of Case 5, left foot of Case 10, and Cases 1, 7, 11, 13, 14, and 16). In all these patients the anatomical result was *very good* and the functional result was *good* with the exception of four feet (both feet of Case 5 and Cases 13 and 16) in which the functional results were classified as only *fair*. In Case 5 the preoperative rocker-bottom deformity was so severe that the child was seriously crippled (Figs. 9-A through 9-F). The deformity was successfully corrected; the child could walk quite well after operation. Therefore, the limitation of active dorsiflexion warrants a lower combined classification. In the two other patients (Cases 13 and 16) dorsiflexion had been weak before operation; at follow-up the range of motion and gait were good.

The combined classification in Cases 4, 9, 12, 15, 17, 19, 22, 23, and 24 was *fair*. This group included: (1) a *very good* anatomical result, combined with absence of active dorsiflexion (Case 24) or tightness of the Achilles tendon (Case 19); (2) a *good* anatomical result, combined with weak dorsiflexion (Cases 15 and 17); or (3) a *fair* anatomical result (Cases 4, 9, 12, 22, and 23). The children in this last group could actively dorsiflex the feet to 90 degrees and, with the exception of Case 12, all had *good* or even *very good* (Case 22) functional results. However, insufficient anatomical correction or overcorrection of the deformity coupled with some instability of the foot (Case 22) would not permit a higher combined classification than *fair*.

There were no serious complications after into-talus transplantation. In a few instances there was superficial sepsis in the anterior wound, but this cleared up in a few days. In only one child, the left foot of Case 5, did slight necrosis of the edges of the wound occur, the U-flap having been made too large.

DISCUSSION

In the combined classification (Column 13, Table I) *very good* results were obtained in those children whose ages at operation ranged from three to six years —an average age of four years and one month. In the group with *good* results, the youngest child was two years and nine months at operation, and the oldest was six years—the average age was five years and two months. In the group with *fair* results the youngest child at operation was one year and eleven months of age, the oldest was nine years — the average age was five years and seven months. In the group with *bad* results, the children's ages at operation ranged from five to seven years—the average was five years and eight months.

These data suggest that the optimum age for the into-talus transplantation is over three years, but not more than six. However, the series is so small that no definite conclusion is warranted. Furthermore, the children on whom this procedure was done were, for the most part, very young; it is impossible to predict

TABLE I

1	2	3	4	5 Into-Talus Transplantation								6	7	8	9	10	11	12	13
Case No. and Foot Involved	Age at Onset of Disease	Previous Tendon Transplants Muscles Transferred and Date	Preoperative Deformity	Preoperative Rating of the Long Muscles of the Leg*								Age at Operation	Muscles Transferred at Operation and Date	Achilles Tendon Lengthened	Reoperation Muscles Transferred and Date	Length of Follow-up	Anatomical Results** (Numerals are Degrees)	Functional Results*** (Flexion in Degrees)	Combined Classification and Remarks****
				Tr	Ta	Tp	Edl and Pt		Ehl	Pl	Pb								
1, R	10 mos.	None	Equinovalgus	3	3	1	3		3	4	4	2 yrs., 9 mos.	Ta, 7/53	Yes	Edl and Pt, 1/55	5 yrs., 8 mos.	*Very good;* (61) 15; foot stable and of normal shape	*Good;* 2; passive dorsiflexion to 90; movement at talocalcaneonavicular joint preserved; walks well in high-laced shoes	*Good;* dorsiflexion would have been stronger if only part of the Edl had been transferred (Figs. 7-A and 7-B)
2, L	10 mos.	Ehl into first metatarsal (Jones suspension), 10/51	Equinovalgus	3	0	2	4		3	3	3	4 yrs., 5 mos.	Edl of second and third toes, 12/53	Yes	None	5 yrs., 2 mos.	*Very good;* (40) 17; foot stable and of normal shape	*Very good;* 3+; movements in all joints preserved; gait essentially normal	*Very good;* had progressive dynamic valgus deformity despite previous Jones suspension
3, L	10 mos.	None	Equinovalgus	5	?	?	4		4	4	4	4 yrs.	Edl and Pt, 11/54	Yes	None	3 yrs., 7 mos.	*Very good;* (40) 14; foot stable and of normal shape	*Very good;* 3+; movements in all joints preserved	*Very good;* see Fig. 8-C for activity of the transplant
4, R	6 mos.	None	Equinovalgus	3	0	1	3		3	3+	3+	1 yr., 11 mos.	Edl and Pt, 3/55	Yes	Pl and Pb, 3/57	4 yrs.	*Fair;* (40) 10; (35) 16; foot stable; mild overcorrection	*Good;* 3; movements at joints preserved, except slight limitation of eversion; walks well in braces (paraplegic)	*Fair;* only one peroneus should have been added to Edl to prevent overcorrection
5, R	10 mos.	Pl into Ta (Mayer operation), 1/52	Equinovalgus (rocker-bottom)	4	0	2	3		4	?	3	6 yrs.	Edl of fourth and fifth toes, Pt, Ehl, Ta, and Pl, 9/55	Yes (with posterior capsulotomy)	None	3 yrs., 6 mos.	*Very good;* (83) 20; extreme rocker-bottom deformity corrected; foot stable	*Fair;* −3; dorsiflexion to 90; movements at talocalcaneonavicular joint preserved; foot stable	*Good;* had progressive equinovalgus deformity despite previous transfer of Pl into Ta; better dorsiflexion on the right because only part of Edl was transferred

5, L		Pl into Ta (Mayer operation), 1/52	Equinovalgus (rocker-bottom)	4	0	2	3	4	?	3	6 yrs., 3 mos.	Edl and Pt, Ehl, Ta, and Pl, 12/55	Yes (with posterior capsulotomy)	None	3 yrs., 3 mos.	*Very good;* (72) 18; extreme rocker-bottom deformity corrected; foot stable	*Fair;* 2; dorsiflexion to 90; slight limitation of eversion; walks well in high-laced shoes	*Good;* see Figs. 9-A through 9-F
6, R	1 yr., 6 mos.	Pl, Pb, invertors, and Edl and Pt transferred into the Achilles tendon to correct calcaneus deformity, 7/54	Equinovalgus	3	0	0	tr†	3	tr	tr	5 yrs.	Ehl, 10/55	No	None	1 yr., 8 mos.	*Bad;* (49) 37; partial correction; foot unstable	*Bad;* 0	*Bad;* massive scarring of Achilles tendon prevented correction of the deformity; first operation had converted calcaneus deformity into equinovalgus deformity
7, L	2 yrs., 3 mos.	None	Equinovalgus	4	0	2	4	4	4	4	5 yrs., 3 mos.	Edl and Pt, 11/55	Yes	None	3 yrs., 4 mos.	*Very good;* (55) 23; (34) 20; foot stable and of normal shape	*Good;* 3; dorsiflexion to 90; movements at the talocalcaneonavicular joint preserved; walks well in high-laced shoes	*Good;* when the Ehl is transferred into the first metatarsal concurrently with the into-talus transplantation, it takes over during the action of dorsiflexion and flattens the longitudinal arch
8, L	8 mos.	None	Valgus	5	3	3	4	4	4	4	3 yrs., 1 mo.	Pl, 12/55	No	None	3 yrs., 2 mos.	*Very good;* (35) 12; (60) 28; foot stable and of normal shape	*Very good;* 3+; full range of movement	*Very good;* there is no dorsal-bunion deformity after Pl transfer; (Figs. 10-A through 10-E)
9, R	About 2 yrs.	All-posteriors†† (except Pl) and Edl and Pt into Achilles tendon to correct calcaneus deformity, 1/56	Equinovalgus	3+	0	tr	tr	4	4	tr	About 9 yrs.	Pl, 6/56	No	None	2 yrs., 9 mos.	*Fair;* (31) 26; (26) 21; partial correction of valgus deformity; foot stable	*Good;* 3; dorsiflexion to 90; movement at talocalcaneonavicular joint slightly limited; walks well	*Fair;* Achilles tendon should have been lengthened; first operation had converted calcaneus deformity into equinovalgus deformity
10, L	10 mos.	None	Valgus	3	0	1	3	?	3	3	6 yrs.	Pl and Pb, 6/56	No	None	2 yrs., 8 mos.	*Very good;* (30) 15; (38) 7; foot stable and of normal shape	*Good;* 3; dorsiflexion to 90	*Good;* no dorsal-bunion deformity in either foot; bad gait due to pelvic obliquity and scoliosis

TABLE I (*Continued*)

1	2	3	4	5 Into-Talus Transplantation								6	7	8	9	10	11	12	13
				Preoperative Rating of the Long Muscles of the Leg*															
Case No. and Foot Involved	Age at Onset of Disease	Previous Tendon Transplants Muscles Transferred and Date	Preoperative Deformity	Tr	Ta	Tp	Edl and Pt		Ehl	Pl	Pb	Age at Operation	Muscles Transferred at Operation and Date	Achilles Tendon Lengthened	Reoperation Muscles Transferred and Date	Length of Follow-up	Anatomical Results** (Numerals are Degrees)	Functional Results*** (Flexion in Degrees)	Combined Classification and Remarks****
10, R		None	Valgus	4	1	2	4		4	4	4	6 yrs., 1 mo.	Pl, 8/56	Yes	Pb and Edl of fourth and fifth toes and Pt into talus, 2/58	2 yrs., 7 mos.	*Very good;* (34) 22; (34) 20; foot stable and of normal shape	*Very good;* 3+; all movements preserved	*Very good*
11, R	1 yr., 1 mo.	None	Equinovalgus	4	2	3	4		3	4	4	5 yrs.	Pl, 6/56	Yes	None	2 yrs., 9 mos.	*Very good;* (48) 14; (39) 26; foot stable and of normal shape	*Good;* dorsiflexion to 90; movement at talocalcaneonavicular joint preserved	*Good;* no dorsal bunion deformity
12, L	9 mos.	All-posteriors (except flexor hallucis longus) into Achilles tendon, 10/52	Valgus	3	4	tr	4		3	tr	tr	5 yrs., 11 mos.	Edl and Pt, 7/56	No	Ta into talus and Ehl into fourth metatarsal, 2/57	1 yr., 7 mos.	*Fair;* (48) 32; (35) 23; partial correction of valgus deformity; foot stable	*Fair;* −3; dorsiflexion to 90; movement at talocalcaneonavicular joint slightly limited; walks satisfactorily with braces	*Fair;* Edl should have been transferred into the talus originally (it would have corrected the valgus and weakened the dorsiflexion sufficiently to prevent further deterioration of the calcaneus)
13, R	About 1 yr.	Edl and Pt into middle part of foot and Jones suspension, 11/55; all-posteriors (except Pl) and Edl and Pt into Achilles tendon, 3/56	Equinovalgus	4	0	0	tr		4	3	tr	About 5 yrs.	Pl, 7/56	No	None	1 yr., 8 mos.	*Very good;* (30) 19; (33) 24; foot stable and of normal shape	*Fair;* −3; dorsiflexion to 95; movement at talocalcaneonavicular joint preserved; walks well	*Good;* Achilles tendon should have been lengthened

14, L	About 1 yr.	All-posteriors into Achilles tendon, 1/56	Valgus	3	2	tr	3	3	tr tr	About 6 yrs.	Ta and Ehl, 7/56	No	None	2 yrs., 7 mos.	*Very good;* (42) 18; (40) 14; foot stable and of normal shape	*Good;* 3+; plantar flexion limited to 100; slight limitation of eversion; walks well with braces (paraplegic)	*Good;* limitation of plantar flexion is due to weak triceps surae
15, L	1 yr., 4 mos.	Pb and Edl into Achilles tendon, 5/56	Valgus	3	2	0	2	2	4 tr	3 yrs., 5 mos.	Pl, 7/56	No	None	2 yrs., 9 mos.	*Good;* (20) 19; (40) 29; slight overcorrection; foot stable	*Fair;* 2; dorsiflexion to 90; movement at talocalcaneonavicular joint preserved; walks well in high-laced shoes	*Fair;* at least one evertor should have been left in place to prevent overcorrection
16, L	3 mos.	All-posteriors into Achilles tendon, 1/54	Equinovalgus	4	0	tr	3	3	tr tr	5 yrs., 1 mo.	Edl and Pt, 7/56	Yes	None	2 yrs., 8 mos.	*Very good;* (25) 14; (29) 8; foot stable and of normal shape	*Fair;* 2; dorsiflexion to 90; movement at talocalcaneonavicular joint preserved; walks satisfactorily in high-laced shoes	*Good;* if only part of Edl had been used, dorsiflexion would have been stronger
17, L	1 yr., 7 mos.	Jones suspension, 1952; von Baeyer's operation, 1953	Equinovalgus	4	0	0	3	3	tr 47	8 yrs., 1 mo.	Ehl, Pb and Edl, and Pt, 8/56	No	None	2 yrs., 7 mos.	*Good;* (32) 18; (36) 19; slight overcorrection; foot stable	*Fair;* 2; passive dorsiflexion to 90; eversion limited; walks well with braces	*Fair;* despite Jones suspension and von Baeyer operation, there was progressive valgus deformity; at into-talus procedure only Edl should have been transferred and Achilles tendon should have been lengthened
18, L	1 yr.	All-posteriors, Edl of second and third toes into Achilles tendon, and Edl of fourth and fifth toes and Pt into middle part of foot, 1954	Valgus	3+	0	tr	?	3+	tr tr	5 yrs.	Edl of fourth and fifth toes, Pt and Ehl, 9/56	Yes (at first operation)	None	1 yr., 5 mos.	*Bad;* (23) 21; foot unstable	*Bad;* 0	*Bad;* operation badly planned

TABLE I (*Continued*)

1	2	3	4	5 Into-Talus Transplantation							6	7	8	9	10	11	12	13
				Preoperative Rating of the Long Muscles of the Leg*														
Case No. and Foot Involved	Age at Onset of Disease	Previous Tendon Transplants Muscles Transferred and Date	Preoperative Deformity	Tr	Ta	Tp	Edl and Pt	Ehl	Pl	Pb	Age at Operation	Muscles Transferred at Operation and Date	Achilles Tendon Lengthened	Reoperation Muscles Transferred and Date	Length of Follow-up	Anatomical Results** (Numerals are Degrees)	Functional Results*** (Flexion in Degrees)	Combined Classification and Remarks****
19, L	1 yr., 1 mo.	All-posteriors into Achilles tendon, 4/54; Edl and Pt into middle part of foot and Jones suspension, 8/54	Equinovalgus	4	0	tr	3	3	tr	tr	5 yrs., 1 mo.	Edl and Pt, Ehl, 9/56	No	None	2 yrs., 6 mos.	*Very good;* (47) 18; foot stable and of normal shape	*Fair;* 2; dorsiflexion to 110	*Fair;* Achilles tendon should have been lengthened
20, L	1 yr.	All-posteriors into Achilles tendon and Achilles tendon lengthened, 6/56	Valgus	4?	0	tr	3	3	tr	tr	7 yrs.	Edl and Pt, 12/56	Yes (at first operation)	Ehl into talus, 7/57; triple arthrodesis, 10/58	2 yrs., 4 mos.	*Bad;* (40) 24; foot unstable; varus deformity	*Fair;* 2	*Bad;* operations badly planned; see Figs. 11-A through 11-D
21, R	1 yr., 2 mos.	None	Valgus	3	0	0	3+	3+	4	4	3 yrs.	Pl and Pb, 10/56	No	None	1 yr., 4 mos.	*Very good;* (44) 21; (46) 20; foot stable and of normal shape	*Very good;* 3+; full range of movement	*Very good*
22, L	10 mos.	All-posteriors into Achilles tendon, 1953	Valgus	5	3	tr	4	4	tr	tr	5 yrs., 2 mos.	Ehl, Ta, and Edl and Pt, 10/56	No	None †	1 yr., 3 mos.	*Fair;* (43) 33; (44) 30; partial correction; slight instability	*Very good;* 3+; full range of movement	*Fair;* technical fault at operation responsible for incomplete reduction of displaced talus
23, R	8 mos.	All-posteriors (except Pl) and Edl and Pt into Achilles tendon, 1956	Equinovalgus	3+	0	tr	tr	4	4	tr	4 yrs.	Pl, 12/56	No	Achilles tendon lengthened and revision of Pl into talus, 6/58	2 yrs., 2 mos.	*Fair;* (42) 42; (37) 37; foot stable and shape improved	*Good;* 3; dorsiflexion to 90; movement at talocalcaneonavicular joint preserved; walks well in braces (paraplegie)	*Fair;* at reoperation Jones suspension done at the same time as longitudinal arch was flattened
24, L	2 yrs.	None	Valgus	5	1	1	3	0	3	3	8 yrs.	Pl, Pb and Edl, and Pt, 12/56	No	None	2 yrs., 3 mos.	*Very good;* (33) 21; (28) 11; foot stable and of normal shape	*Bad;* 0; dorsiflexion to 90; eversion slightly limited; walks well with brace	*Fair;* strength of evertors over-rated; the Pl and Pb muscles appeared pale at operation

* The ratings are approximate and range from 0 (paralyzed) to 5 (normal). The abbreviations for the muscles are: Tr = triceps surae; Ta = tibialis anterior; Tp = tibialis posterior; Edl and Pt = extensor digitorum longus and peroneus tertius; Ehl = extensor hallucis longus; Pl = peroneus longus; and Pb = peroneus brevis.
** The preoperative taloplantar angle, in degrees, is inside the parentheses; the angle at follow-up examination, outside. When two sets of figures are listed, the second set is the talocalcaneal angle (see text).
*** A rating of 3 means the patient can dorsiflex the foot actively against gravity to a right angle (see text).
**** The combined classification is based on both anatomical and functional results (see text).
† tr = transferred at a previous operation.
†† All-posteriors = all muscles running posteriorly to the ankle joint: tibialis, flexor hallucis longus, flexor digitorum longus, peroneus longus, and peroneus brevis.

what effect growth will have on the ultimate results. The results reported here must therefore be considered preliminary.

The approximate preoperative power of the long muscles of the leg of the twenty-four patients is tabulated in Column 5 of Table I. However, the ratings must be accepted with some reservation because evaluation of muscle power in small, uncooperative children may not always be accurate.

In all patients in the *very good* group in the combined classification, the transferred muscles were rated before operation as *4*. In six of the group of nine *fair* results, the preoperative rating of the transferred muscles was also *4*; their combined classification of only *fair* was owing, in four instances, to their inferior anatomical results (Column 11, Table I). In general, as might be anticipated, the results were superior in those patients who had strong evertors available for the into-talus transplantation.

Listed in Column 3 of Table I are the tendon transplantations performed prior to the into-talus procedure. In five children (Cases 2, 5, 13, 17, and 19) the valgus deformity progressed despite diverse tendon transplantations to different locations in the front part of the foot. In the patient of Case 5 the deformities culminated in rocker-bottom feet with taloplantar angles of 83 and 72 degrees, respectively. These deformities were corrected by the into-talus transplantation (Figs. 9-A through 9-F).

Column 4 in Table I describes the preoperative deformity. There were fifteen feet with equinovalgus and eleven feet with valgus deformity.

Twelve patients had a calcaneus deformity—or a tendency toward it—originally (Cases 6, 9, 12, 13, 14, 15, 16, 18, 19, 20, 22, and 23); tendon transplantations into the Achilles tendon had been performed prior to the into-talus procedure. These twelve preliminary operations had resulted in the development of six equinovalgus and six valgus deformities. The subsequent into-talus transpositions resulted in the combined classification of *good* in three feet, *fair* in six, and *bad* in three. There were no *very good* results.

The inferior results were due, among other causes, to the shortening of the Achilles tendon—a frequent occurrence after transplantation of all posterior muscles into this tendon—in six patients (Cases 6, 9, 13, 17, 19, and 23) or to instability of the foot, caused by transfer of these muscles, in two patients (Cases 18 and 22). All results with a combined classification of *very good* were obtained in operations for correction of equinovalgus (Cases 2 and 3) or valgus deformities (Cases 8 and 21 and right foot of Case 10). Six of the nine *good* results followed correction of equinovalgus (Cases 1, 7, and 11), valgus (left foot of Case 10), and rocker-bottom deformities (both feet of Case 5). Three of the nine *fair* results followed correction of equinovalgus (Cases 4 and 17) or valgus deformities (Case 24). All of the *bad* results occurred in feet that originally had had calcaneovalgus deformities. These deformities had been converted into valgus or equinovalgus deformities by a previous operation in which most of the muscles had been transplanted into the Achilles tendon.

It would appear, therefore, that the best results can be anticipated when the into-talus procedure is carried out for the correction of valgus, equinovalgus, or rocker-bottom deformities. In view of these results one might consider, under certain circumstances, the use of into-talus transplantation to correct congenital rocker-bottom deformity [7] and, perhaps, severe juvenile flat-foot deformity. However, I have had no personal experience with this procedure in the treatment of either of these deformities.

The muscles used for the into-talus transplantation are listed in Column 7 of Table I. To be noted especially when reading this column are those feet that

required reoperation (Column 9). In some instances, in addition to the evertors, the extensor hallucis longus and the tibialis anterior were used for transplantation into the talus. As might be anticipated, the best results (Column 13) were obtained in those feet in which one (or only part of the extensor digitorum longus) or at the most two muscles were used for the into-talus transplantation (Cases 1, 2, 3, 7, 8, 10, 11, 13, 14, 16, and 21). These were the feet with a lesser degree of muscle weakness. In the results classified as *very good*, the average number of muscles transplanted was 1.4 per cent; in *good* results, 1.9 per cent; and in *fair* results, 2.1 per cent. The muscles most successfully, and most frequently, used for the operation were the peroneus longus and extensor digitorum longus (or part of it) combined with the peroneus tertius. The extensor hallucis longus was used in the feet with a *bad* classification. Either alone (Case 6) or in combination with other muscles, it was not used in any foot in the *very good* group.

In into-talus transplantation, the extensor digitorum longus and the peroneus longus should be considered first, followed closely by the peroneus brevis. If possible, transplantation of the extensor hallucis longus should be avoided.

Six children had additional operations after the into-talus procedure (Column 9, Table I). In three (Cases 1, 12, and 20) one muscle was added and in two (Cases 4 and 10) two muscles were added to those originally transplanted into the talus. In the sixth child (Case 23) the muscle transferred (the peroneus longus) was reinserted into the talus under greater tension. In one of these six children (Case 20), a third operation was performed—triple arthrodesis. This made a total of seven additional operations.

Of the seven reoperations two resulted in marked improvement (Cases 1 and 10) and three in slight improvement (Cases 4, 12, and 23). The sixth child's (Case 20) condition was unchanged after reoperation; consequently, sixteen months later, when the child was nine and a half years old, triple arthrodesis was performed because of the varus deformity (Figs. 11-A through 11-D).

In six instances (Cases 6, 9, 13, 17, 19, and 23), despite the presence of fixed equinus deformity, the Achilles tendon was not lengthened (Column 8, Table I). Failure to do this was primarily responsible for the inferior results obtained in these patients.

In three instances (Cases 7, 20, and 23) a Jones suspension was performed concurrently with the into-talus transplantation (Column 13, Table I) and in one reoperation (Case 12) the extensor hallucis longus was transferred into the fourth metatarsal (Column 9). In all these patients, the extensor hallucis longus subsequently took over the function of dorsiflexion at the ankle from the muscles transplanted into the talus, causing flattening of the longitudinal arch of the foot in two patients. The better leverage of the extensor hallucis longus with its attachment to the front part of the foot at a greater distance from the transverse axis of the ankle joint appeared to be responsible for this situation. In view of this, it is now thought that no other tendon transplantation to the front part of the foot should be carried out simultaneously with the into-talus transplantation.

An analysis of the *bad* and *fair* results in the combined classification (Column 13) indicates that the following factors are responsible:

1. Failure to correct completely the preoperative deformity of the foot—equinus in six patients and medial displacement of the talus in four (Cases 6, 9, 12, and 22);

2. Wrong planning, bad indications, and technical faults (Cases 4, 6, 12, 17, 18, 20, and 22);

3. Incorrect evaluation of the power of the muscles before operation—apparently, some of the invertors of the foot were stronger than originally rated

and they recovered even more strength after their antagonists were removed from the fore part of the foot, resulting in overcorrection (Cases 4 and 15). The strength of some of the evertors used for transplantation into the talus was over-rated (Case 24);

4. Plication of the capsule on the medial aspect of the talocalcaneal joint and failure to appreciate the deforming effect of the short muscles on the medial aspect of the foot (abductor hallucis), with resultant overcorrection of the valgus deformity in some instances;

5. Loss of power of dorsiflexion when all the anterior muscles were used for transplantation, with resultant equinus deformity in some children (Cases 5, 6, 17, 19, 20, and 24) and reduction in functional capacity of the foot.

Best results were achieved in the feet with less severe paralysis, in which only one or two muscles were needed for transplantation, leaving at least one evertor and one muscle on the medial side of the foot to provide side-to-side stability and stronger dorsiflexion.

Despite the transference of the peroneus longus in twelve feet, only two dorsal bunions were observed. One had been present in a patient (Case 5) since 1952, at the time of the original transfer of the peroneus longus into the tibialis anterior. In the other patient (Case 13) it was probably due to the Jones suspension, which had been performed in 1955. From this small experience, it would appear that the removal of the downward pull of the peroneus longus on the first metatarsal by transferring its tendon into the talus does not necessarily result in dorsal-bunion deformity, unless the procedure is combined with a Jones suspension. If a Jones suspension has been done, the peroneus longus should not be used for the into-talus transplantation.

It should be noted that of the twenty-six into-talus transplantations performed, the movements at the talocalcaneonavicular joints remained normal after twelve procedures and were moderately limited after eleven. In one patient the joints were arthrodesed, and after two procedures no notes were taken.

SUMMARY AND CONCLUSION

An operation for the correction of paralytic, dynamic, valgus deformity of the foot of a child after poliomyelitis is presented. The procedure consists in the surgical mobilization of the medially and downward displaced talus, transfer of one or more of the deforming muscles (evertors of the foot) into the neck of the talus to maintain its corrected position, and, when necessary to correct equinus deformity, lengthening of the Achilles tendon.

An analysis of the results in twenty-six operations and seven reoperations is presented.

Into-talus transplantation seems to be best suited for the correction of paralytic, dynamic equinovalgus, valgus, and rocker-bottom deformities in children from three to six years old. If the procedure is performed on a foot with established changes in the shape of the tarsal bones, it may improve the shape of the foot, and hence contribute to more normal growth (Figs. 9-A through 9-F).

When moderate displacement of the talus is present and the difference in strength of the so-called true invertors and evertors of the foot is not marked, only the extensor digitorum longus and the peroneus tertius—or better still, only a few slips of the common extensor—need be used for the transplantation.

On the other hand, if the deformity is more pronounced, one or both peronei, or one peroneus with a part of the extensor digitorum longus, should be transferred.

When the peronei are transferred to the talus, the direction of the pull is

more from the lateral side than when the extensor digitorum longus is used. Accordingly, the peroneus longus and brevis should be used in feet in which the medial displacement of the talus is more accentuated (Figs. 10-B and 10-D).

An additional advantage to using one or both of the peroneal muscles for the into-talus transplantation is that they contract automatically during the stance phase of gait and during push-off. The peronei may therefore be expected to pull the talus upward during weight-bearing and thus prevent its gliding medially off the calcaneus during the crucial phase of gait—when the talus bears the full thrust of the body's weight.

This tendon transplantation should not be carried out concurrently with other tendon transplantations to the fore part of the foot, for reasons previously explained (Cases 7, 20, and 23).

Transplantation of more than two muscles into the talus should be avoided, especially if it requires removal of muscles from the dorsum of the fore part of the foot, with resultant weakening of dorsiflexion. Reconstruction of the medial capsule of the talocalcaneal joint should be done only in those feet in which evertors, which are not transplanted, are observed at operation to have some shortening. Reconstruction of the medial capsule should not be done in feet in which all evertors have been transferred, because under these circumstances overcorrection is bound to occur.

The onset of poliomyelitis in the twenty-four children operated on occurred at an average age of one year and two months. The duration of follow-up averaged only two years and eight months—from one year and three months to five years and eight months. It is impossible at this time to predict what the effect of growth will be on the ultimate results. The preliminary results, however, seem to indicate that consideration should be given to the possibility of establishing direct, dynamic muscle control of the unstable talus from above before a decision is made to eliminate permanently the subtalar joint of a small child. It appears, in selected patients, that the establishment of so-called dynamic stability at the ankle joint may exert a beneficial influence on the subtalar joint and the joints of the middle portion of the foot to the extent that triple arthrodesis may be delayed with safety, or even not done at all.

NOTE: My thanks are due to Dr. Leo Mayer for his constant encouragement.

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Desmoplastic Fibroma

A Report of Three Cases

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We have seen recently three examples of an uncommon bone tumor that was reported first by Jaffe in 1958 and called *desmoplastic fibroma*. These cases were individually of such an unusual nature that we felt they should be reported.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Roentgenogram of the right humerus of a woman, thirty-three years old, shows the advanced state of the lesion and its roentgenographic similarity to metastatic adenocarcinoma of the thyroid or kidney. (W.U. Ill. No. 54-125.)

Fig. 1-B: The characteristic gross features of desmoplastic fibroma are shown on this hemisection of the resected lesion. The glistening collagenous stroma, many cystic areas, absence of metaplastic or neoplastic bone, expansion and destruction of the cortex, and ability to grow to massive size are evident. (W.U. Ill. No. 53-6405.)

CASE 1. I. C., a white farm housewife, thirty-three years old, was first admitted to Barnes Hospital on November 13, 1953, complaining of pain in the right shoulder which had begun nine years previously. There was no history of trauma. Symptoms had occurred during the first trimester of her first pregnancy, and, at that time, a sling was necessary for the relief of pain. The pain disappeared after delivery and did not return during the two rapidly ensuing pregnancies. Approximately six years later the pain returned gradually with associated swelling. This pain progressed for the next three years; a roentgenogram was then made because of persistent pain and obvious tumefaction (Fig. 1-A). The roentgenogram demonstrated a large lesion involving the proximal half of the right humerus with nearly total destruction of that entire area and replacement of bone with a mass of soft-tissue density. The roentgenographic interpretation suggested a metastatic lesion of either thyroid or renal origin.

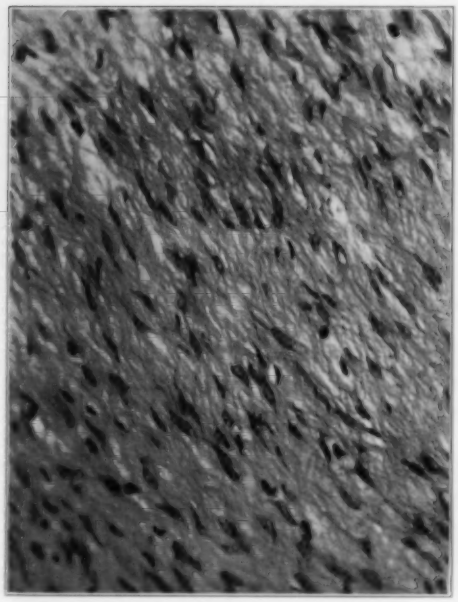

FIG. 1-C

FIG. 1-D

Fig. 1-C: Photomicrograph shows the prominent intercellular collagen with relatively sparse, small, uniform nuclei without mitotic activity. This area of the lesion is more cellular than others of the same lesion (hematoxylin and eosin, × 400). (W.U. Ill. No. 54-103A.)

Fig. 1-D: Roentgenogram, made in the immediate postoperative period following the reconstructive procedure done three months after resection, shows the fibular graft fastened to the remaining humeral shaft with one screw. (W.U. Ill. No. 54-1365.)

Physical examination was within normal limits except for the right upper extremity. A firm, slightly tender mass was found involving the proximal portion of the arm, enlarging it to twice the diameter of the contralateral limb at this level. The mass extended from the acromion to the junction of the middle and distal thirds of the humerus, filling the axilla and severely limiting glenohumeral motion. No abnormalities of the remainder of the extremity were found and no evidence of renal or thyroid lesions was noted. Laboratory studies were all within normal limits.

On November 14, 1953, an incisional biopsy was done. The initial histological diagnosis was "a well-differentiated fibrosarcoma that would not be expected to metastasize" (L.V.A.). On November 20, 1953, an excision of the proximal two-thirds of the humerus was done by Dr. J. Albert Key in which all major nerves and vessels were preserved.

The resected specimen was a mass measuring fifteen by ten by eight centimeters, with an attached portion of the humeral shaft (Fig. 1-B). The head of the humerus was entirely replaced, the tumor surface being smooth and covered by a thin, yellowish, translucent membrane. Throughout, the tumor was uniform with numerous, small, cystic spaces containing clear, yellowish fluid. No bone was present within the lesion. The histological findings in this specimen were identical with those of the biopsy (Fig. 1-C). Tumor tissue was, however, found at the margin of the humeral transection.

On February 4, 1954, a fibular replacement was carried out (Fig. 1-D); no evidence of tumor was found on exploration of the wound and biopsy of various areas. The only postoperative complication was a transient, peroneal palsy on the side of the fibular donor site.

The patient continued to do well without recurrence of the lesion except for fracture of the fibular graft in 1957 (Fig. 1-E). The fracture has remained ununited since, but the patient has been able to do all of her household duties without pain and with only minimal disability. At the time of writing fifteen years have elapsed since the onset of symptoms and six and one-half since surgical resection.

CASE 2. J. H., a seventeen-year-old white female college student, was admitted to Barnes Hospital on July 19, 1959, having suffered a fracture of the left humerus following a blow to the arm seven months previously. A roentgenogram made at that time showed a large lesion expanding

FIG. 1-E

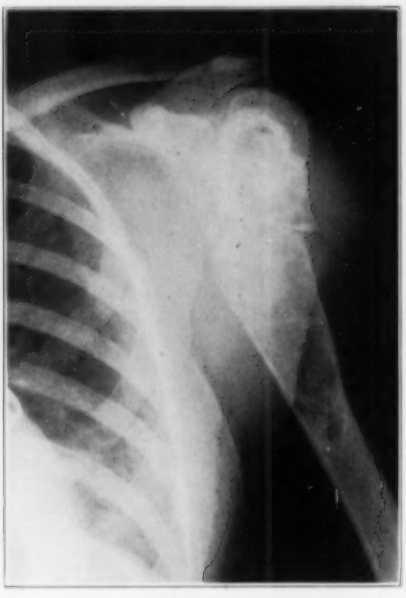

FIG. 2-A

Fig. 1-E: Roentgenogram of the fibular graft approximately four years after operation reveals an unhealed fracture of the graft of several months' duration. It was in this state at the time of writing. However, painless and relatively adequate motion was present. (W.U. Ill. No. 58-3854.)

Fig. 2-A: Case 2. Roentgenogram of the left shoulder of a seventeen-year-old girl shows a healed pathological fracture that had been treated conservatively. A lesion somewhat similar to a unicameral bone cyst is seen extending into the epiphyseal area of the humerus. (W.U. Ill. No. 59-5464.)

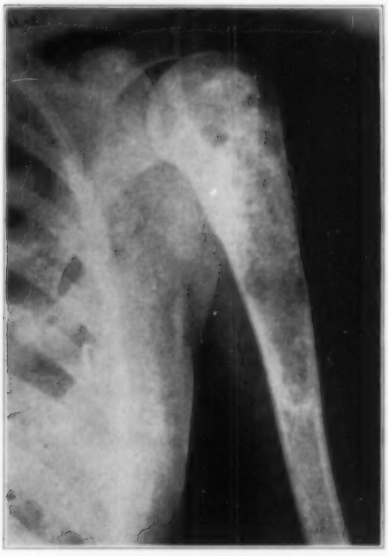

FIG. 2-B

FIG. 2-C

Anteroposterior and lateral roentgenograms of the left shoulder made six months later, just prior to surgery. Reaction to the fracture is seen and some extension of the lesion is evident. (W.U. Ill. Nos. 59-4784 and 59-4785.)

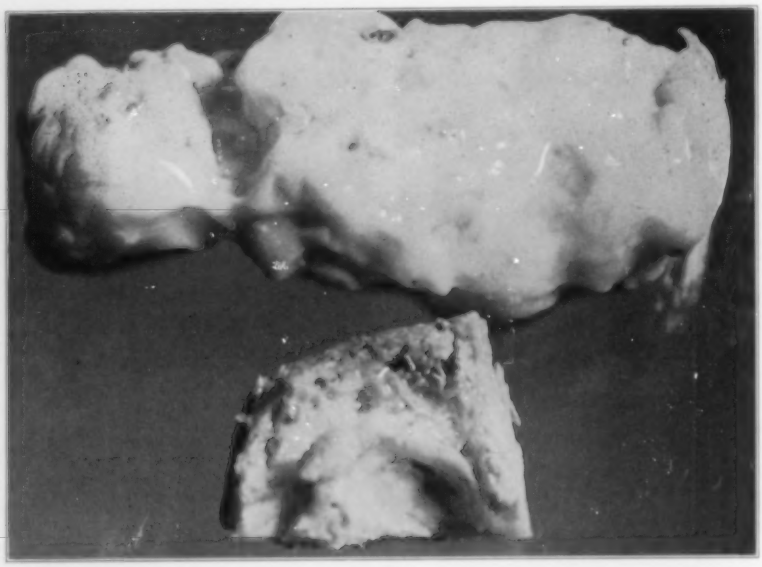

FIG. 2-D

A portion of the removed tumor and the undersurface of a piece of the overlying cortex. (W.U. Ill. No. 59-4861.)

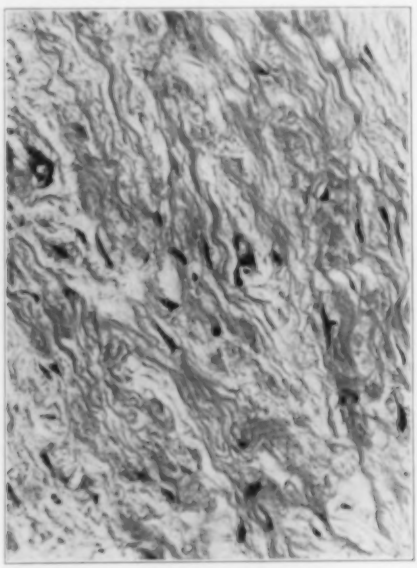

FIG. 2-E

FIG. 2-F

Fig. 2-E: Photomicrograph shows a relatively acellular portion of the tumor. Collagenous tissue is quite evident. Other areas of this same tumor appear similar to the pattern seen in Figs. 1-C and 3-B (hematoxylin and eosin, × 215). (W.U. Ill. No. 59-7043.)

Fig. 2-F: Roentgenogram made six months after curettage and autogenous bone-grafting. Incorporation of the graft appears to be progressing adequately and no recurrence is apparent. At one year motion was normal and there were no symptoms. (W.U. Ill. No. 60-56.)

the proximal portion of the humerus to a slight degree. It extended into the humeral head and had a sclerotic, apparently trabeculated margin. A pathological fracture of the surgical neck of the humerus was present. The clinical and roentgenographic impression was that of unicameral bone cyst. The fracture healed promptly with the arm immobilized in a hanging cast but the patient

FIG. 3-A

Case 3. Roentgenogram shows an expanding lesion of the right ilium in an eight-year-old boy. The extent of involvement of the acetabular region is quite marked. (W.U. Ill. No. 60-1099.)

noted in the period prior to surgery some soreness, usually at night and with changes in the weather.

At the time of admission, the history was otherwise non-contributory and there was no history of trauma prior to the fracture. Laboratory studies were unremarkable and a roentgenographic skeletal survey was within normal limits except for the left humerus (Figs. 2-A and 2-B). There had been some apparent filling-in of the lesion about the fracture site. Physical examination revealed some thickening of the upper portion of the left arm; however, there was no tenderness, discoloration, bruit, or increased heat. A full range of painless motion was present in both the shoulder and the elbow. Psoriatic lesions were present over the body; otherwise, physical examination was negative.

On July 20, 1959, the lesion was surgically explored and unroofed by Dr. H. Relton McCarroll. A mass of rubbery, whitish tissue was found (Fig. 2-C) and a thorough curettage was carried out. Autogenous iliac-bone chips were used to fill the cavity. The histological diagnosis was desmoplastic fibroma (Fig. 2-D).

The postoperative course was without complications. Roentgenograms made six months later showed no evidence of recurrence and suggested that the area filled with bone graft was being adequately incorporated (Fig. 2-E). The patient was without evidence of recurrence and without pain or limitation of motion one year after operation and one and one-half years from the onset of symptoms.

CASE 3*. K. J., an eight-year-old boy, was admitted to the hospital because of slight aching in the right hip of four months' duration. Three weeks before admission a limp was first noticed. Prior to roentgenographic studies, Legg-Calvé-Perthes disease was suspected. However, the roentgenogram disclosed a large, expanding lesion of the right ilium (Fig. 3-A). This involved the juxta-articular area of the superior aspect of the hip joint. Apparent trabeculation was present and an aneurysmal bone cyst or hemangioma was suspected. When the lesion was surgically exposed, a rubbery, whitish tumor was found that in general peeled out easily; some portions adjacent to the margin were more adherent, however. Thorough curettage was carried out, and a bone graft was inserted to reinforce the acetabulum. The other areas of the defect were not filled with grafts. Histologically, the lesion was typical of a desmoplastic fibroma (Fig. 3-B). Postoperatively, the patient had no complications. For six months weight-bearing was not allowed.

* The history, tumor tissue, and roentgenograms of this case were kindly furnished by Dr. Edward G. Ewer, Oakland, California.

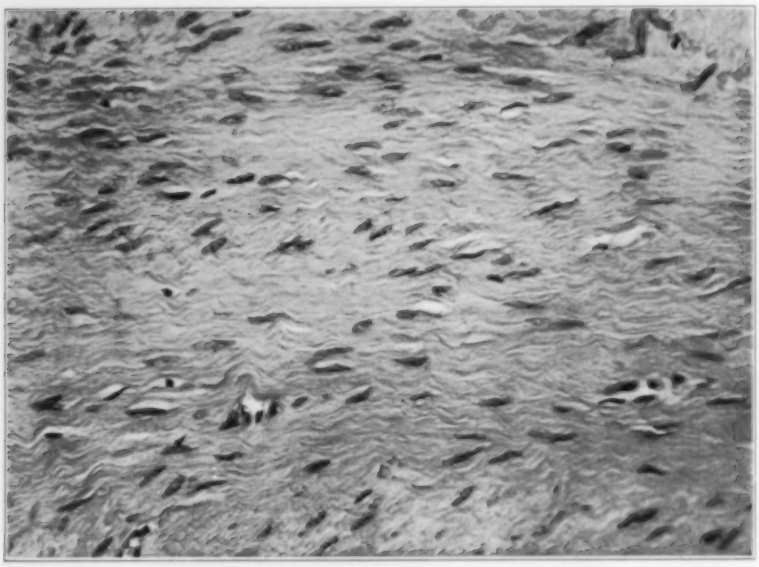

FIG. 3-B

The characteristic collagenous predominance with small, uniform fibroblasts is shown in this photomicrograph (hematoxylin and eosin, × 350). (W.U. Ill. No. 60-3396A.)

FIG. 3-C

Roentgenogram made thirteen months after operation shows incorporation of the bone graft placed above the acetabulum. The remainder of the cavity after curettage was not filled with bone grafts and has not filled in with bone spontaneously in the interim. At twenty-one months after surgery, there was no evidence of recurrence and the patient had a normal gait. (W.U. Ill. No. 60-3742.)

A roentgenogram made thirteen months after surgery showed incorporation of the bone graft placed above the acetabulum (Fig. 3-C). Twenty-one months after operation the patient was without clinical symptoms of recurrence. His gait was normal and no further restrictions were placed upon his activity.

DISCUSSION

Jaffe first described this entity in 1958 when he recorded five cases in his book *Tumors and Tumorous Conditions of the Bones and Joints.* He formulated for these lesions the name *desmoplastic fibroma.* This designation seems quite logical in that it describes its densely fibrous character, suggests its histological similarity to abdominal and extra-abdominal desmoid tumors, and differentiates it from other fibrous lesions of bone.

The gross features of these lesions are characteristic. The tumor has a uniform, tough, rubbery consistency with occasional, small loculi of yellowish fluid [2]. The main body of the tumor at curettage peels out easily; at the junction with bone at its periphery it may be somewhat more adherent. The tissue is usually gray or gray-white and is devoid of bone or calcification except at the extreme periphery. Microscopically the tumor consists of abundant, richly collagenous, intercellular material in which there is a relatively small number of small, consistently similar fibroblasts of benign appearance. The relative cellularity and the pattern of collagen may vary between different cases and, more strikingly, between various areas of the same lesion. Bone formation, metaplastic or otherwise, is not a feature of this lesion. Although the lesion has been known to recur after treatment, the benign histological character has remained unchanged [2].

As seen on the roentgenogram the tumor is usually centrally located and expands the bone cortex. The lesion itself is radiolucent and has a sclerotic and irregular border, giving the illusion of trabeculation similar to that found in a unicameral bone cyst or metaphyseal fibrous defect. The apparent trabeculation and bone expansion may also be suggestive of an aneurysmal bone cyst or even a chondromyxoid fibroma. In an extremely large lesion, the tumor may replace the entire bone and give an appearance not unlike that occasionally seen in metastatic adenocarcinoma of thyroid or renal origin particularly when the lesion is located, as in Case 1, in the proximal portion of the humerus which is a common site for metastatic thyroid carcinoma. The desmoplastic fibroma differs from monostotic fibrous dysplasia in that the tumor tissue does not undergo osseous metaplasia, thus there are no radiopaque areas in the tumor itself. Medullary fibrosarcoma may also give a similar roentgenographic appearance.

Interestingly enough, none of our tumors was located in any of the same areas as those reported by Jaffe. He reported three tumors in the tibia, one in the femur, and one in the scapula. One of ours was in the ilium and two were in the humerus. Jaffe states that in none of his cases was there extension into the actual epiphyseal end of the bone. Extension into this area was present in both of our tumors in the humerus. Our patients were eight, seventeen, and thirty-three years old; Jaffe's were nine, ten, nineteen, twenty-one, and forty years old. As regards sex, we had two females and one male while Jaffe had three females and two males. Thus, there is a rather wide age range and, although there were five female patients to three male patients, no significant sexual predilection has been established.

Clinical signs and symptoms vary with the location and size of the lesion. In no instance has trauma appeared to play a part. We place no significance on the coincidence of onset of symptoms with pregnancy in Case 1.

The tumors have all responded well to adequate local resection, as would be expected on the basis of their histological pattern. Jaffe reported one tumor that recurred twice but was eventually controlled by repeated curettage. In such a well differentiated fibroblastic tumor, radiation therapy would not appear

indicated. We advise adequate, open biopsy and curettage or resection, as required by the individual case. If the nature of the lesion is understood, amputation should rarely if ever be necessary.

Case 1 shows that the lesion, if untreated, can progress to large proportions. Furthermore, despite the fact that the tumor extended microscopically to the margin of the initial excision, no remnant was found at the reconstructive procedure done three months after excision of the tumor and there was no recurrence in six and one-half years. This tumor, as was one of Jaffe's, was originally diagnosed as a well differentiated fibrosarcoma, with some reservations as to its exact nature [1]. Case 2 was presented at the Instructional Course Dinner of The American Academy of Orthopaedic Surgeons in January 1960. It was understandably and interestingly confused with a unicameral bone cyst—a lesion with which it has roentgenographic but no histological similarities. It was in the proximal humeral region of a young woman and had caused a previous pathological fracture. In Case 3 the lesion was large and had an unusual location. The roentgenogram suggested either aneurysmal bone cyst or chondromyxoid fibroma.

Since we, as well as Jaffe, had originally diagnosed this lesion as well differentiated fibrosarcoma, we feel it is possible that other examples of this tumor are similarly classified in the files of other physicians. They possibly have also been classified as cases of cured fibrosarcoma. A review then of surviving cases of fibrosarcoma might well bring to light other examples of this rather distinctive lesion.

SUMMARY

Three unusually interesting examples of desmoplastic fibroma—a benign bone tumor of fibroblastic origin described previously as a separate entity only by Jaffe—are presented. These were of unusually large size and occurred in areas not previously noted. Two of the tumors crossed into the epiphyseal areas of bone—a behavior not previously recorded. The lesion occurs in a wide age range with no significant sexual predilection. The symptoms vary with the size and location of the tumor. On gross examination the tumor is white or gray-white with a uniform, tough, rubbery consistency and contains occasional loculi of yellowish fluid. Roentgenographically it is a radiolucent, usually centrally located lesion that may expand the bone, having a slightly sclerotic and apparently trabeculated border. Microscopically the lesion consists of abundant, richly collagenous, intercellular material devoid of bone formation in which there is a relatively small number of small, consistently similar fibroblasts of benign appearance. Treatment should consist in incisional biopsy and then curettage or resection as required by the individual case. Amputation should rarely if ever be necessary. The tumor may be clinically and histologically easily confused with fibrosarcoma, thus an accurate diagnosis is necessary in determining proper therapy. It is suggested that other examples of this tumor exist in other institutions, probably classified as well differentiated fibrosarcoma.

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Well Differentiated Fibrosarcoma of the Calcaneus

Report of a Case Treated by Resection

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Tumors of the calcaneus which can be treated adequately by resection of the whole bone are rarely encountered [10,11,13]. Miltner and Wan recorded a case of giant-cell tumor of the calcaneus in which the entire bone was excised successfully. Ottolenghi and Petrocchi successfully replaced a calcaneus resected for chondromyxosarcoma with a calcaneus from the bone bank. It is the purpose of this article to record a well differentiated fibrosarcoma of the calcaneus which was treated by total resection of the bone. The diagnosis of well differentiated fibrosarcoma was established by anatomical studies of the lesion by Dr. Henry L. Jaffe.

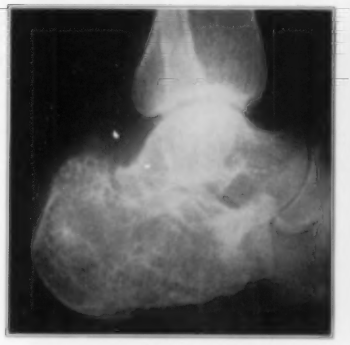

Fig. 1

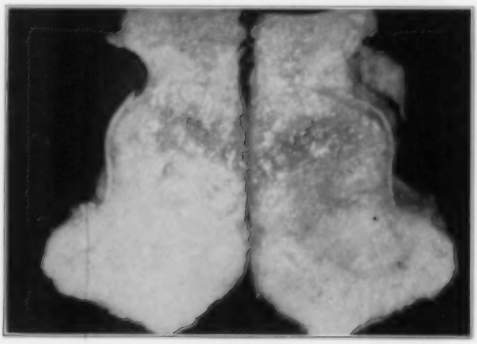

Fig. 2

Fig. 1: Roentgenograms made March 22, 1955, showing a honeycombed appearance and coarse trabecular markings in the body of the calcaneus. The posterior superior cortex appears somewhat moth-eaten and irregular.

Fig. 2: Photograph of sectioned specimen of calcaneus.

CASE REPORT

Mr. M.M., aged forty-five was first examined at St. Joseph's Hospital on March 21, 1955, because of pain in the left heel. In March 1953, he had accidentally struck his left heel on a steel beam. The pain had developed insidiously after this and increased gradually. About four months after onset he began to walk with a limp on the left side. Treatment by medication and physical therapy failed to give relief. In December 1953 (nine months after onset), the pain became constant, even when at rest and the patient began to use crutches. His general health was good and there was no known loss of weight. He was referred to the hospital by his attending physician with a diagnosis of Paget's disease with malignant degeneration of the calcaneus.

When examined the patient appeared to be in good general health. Local examination revealed one inch of atrophy of the left calf and enlargement of the left heel with tenderness on all aspects of the calcaneus. Dorsiflexion of the foot was complete but plantar flexion was limited to 120 degrees. There was no subtalar motion. Pain was elicited at the extremes of ankle motion and on attempted passive movement of the subtalar joint. The inguinal glands were neither enlarged nor tender. The remainder of the physical examination revealed no other abnormality. Roentgenograms of the chest were negative and a general skeletal survey showed no evidence of Paget's disease or other abnormality except in the left calcaneus.

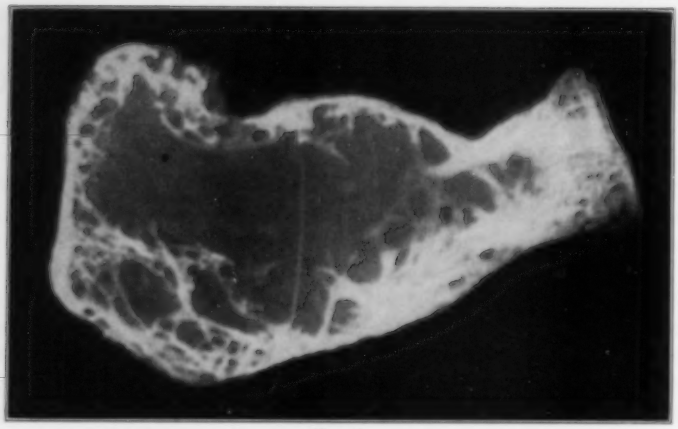

FIG. 3

Roentgenogram of sectioned specimen of calcaneus.

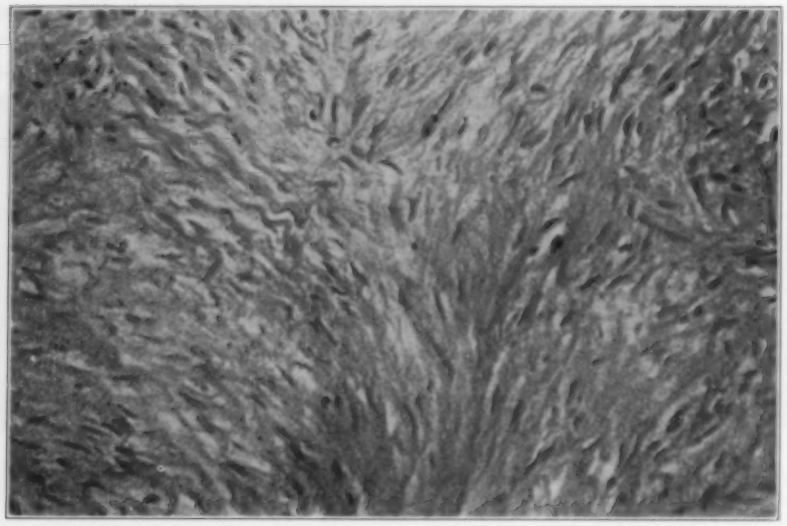

FIG. 4

Photomicrograph (× 125) showing the histological pattern of well differentiated fibrosarcoma.

A lateral roentgenogram of this bone made on March 22, 1955 (Fig. 1), showed enlargement of the tuberosity and some collapse of the articular surface with loss of the tuber angle. The normal trabecular pattern was replaced by a coarse multiloculated appearance which involved all but the anterior end of the bone. On the posterior superior aspect the cortex was expanded and irregular, indicating that the process had perforated the cortex in this region.

Laboratory data: Hemoglobin, 12 grams per 100 cubic centimeters; red blood cells, 4,200,000; white blood cells, 8,500 per cubic millimeter, with 62 per cent polymorphonuclear cells.

Chemical studies: Serum calcium, 9.8 milligrams per 100 cubic centimeters; serum phosphorus, 2.8 milligrams per 100 cubic centimeters; serum alkaline phosphatase, 2.3 Bodansky units.

On March 30, 1955, operation was performed with a pneumatic tourniquet on the thigh. A Gaenslen incision on the plantar aspect of the foot was used beginning in the mid-line directly opposite the tuberosity of the fifth metatarsal bone, and extending proximally over the center of the heel following the tendo achillis upward for a distance of three inches. The entire calcaneus was removed leaving the periosteum intact on the resected bone (Fig. 2). The tourniquet was then released and hemostasis was secured. The distal end of the Achilles tendon was sutured to the proximal end of the plantar fascia with the foot in complete equinus, and the wound was closed in layers. A plaster boot was applied to maintain the foot in equinus.

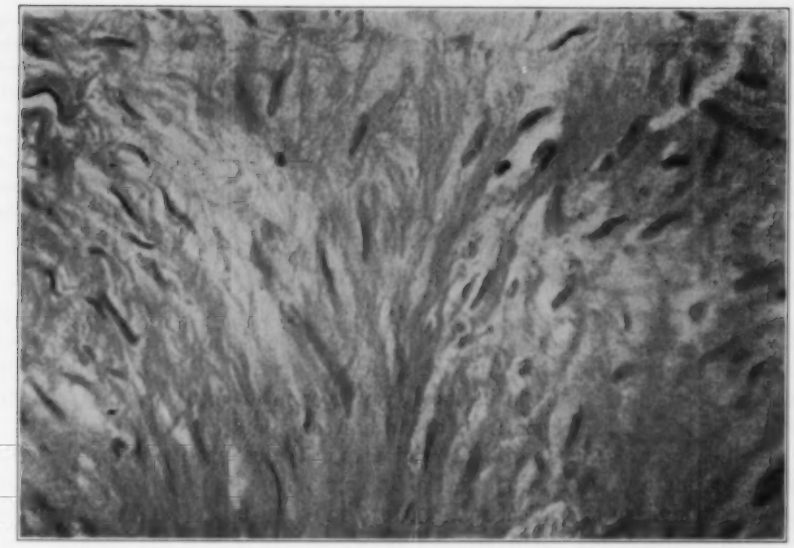

FIG. 5

Photomicrograph (× 250) showing the uniform size of the tumor fibroblasts.

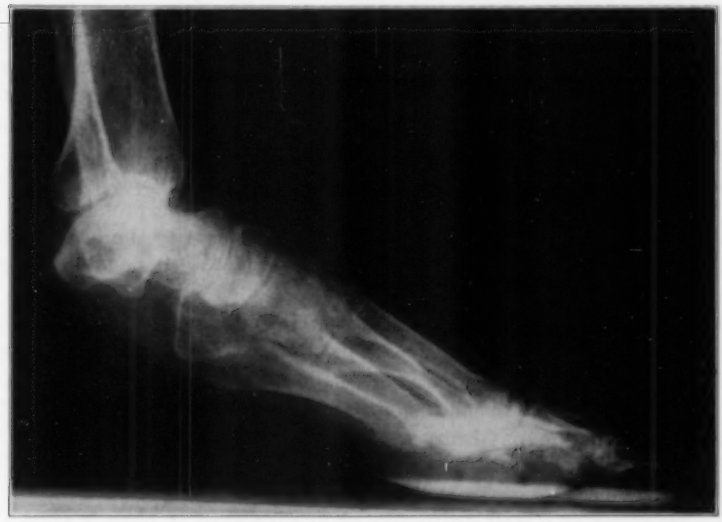

FIG. 6

Lateral roentgenogram of the foot bearing weight. Note normal alignment of remaining bones.

On gross inspection the calcaneus was found to be almost entirely filled by the tumor. The tumor was white and rather firm. In its central portion it had a somewhat collagenous appearance. A roentgenogram of the sectioned specimen (Fig. 3) revealed destruction of bone in the central portion with preservation of the surrounding cortex and a few remaining areas of normal cancellous bone, particularly in the anterior portion.

Microscopic appearance (Fig. 4) of the tumor tissue showed elongated and spindle-shaped fibroblasts with collagen fibers between the cells arranged in whorls and interlacing patterns. A few mitotic figures were present. There was no evidence of anaplasia or bone formation. The elongated fibroblasts and their nuclei were of uniform size (Fig. 5). Sections of bone showed no evidence of Paget's disease.

The plaster boot was removed six weeks after operation at which time there was strong active

plantar flexion. The postoperative course was uneventful except for a small area of skin necrosis on the heel measuring one inch in diameter which was excised and subsequently covered with a skin graft. The patient began to walk with crutches after the wound was healed and was discharged from the hospital on June 30, 1955 (three months after operation). He was supplied with a heel-replacement support in his shoe and since April 1956 he has been walking with the aid of a cane. He was last examined on March 13, 1960, when roentgenograms showed no pulmonary metastasis. At that time he had no pain and was able to walk about twenty blocks. The contour of the foot was essentially normal except for the absence of the heel. There was no evidence of local recurrence on physical examination, and, on weight-bearing, normal alignment of the remaining bones of the foot was maintained (Fig. 6).

DISCUSSION

Central fibrosarcoma of bone has been established as a diagnostic entity[1,2,3,4,6,9]. Jaffe's definition of fibrosarcoma of bone as a "primary malignant fibroblastic tumor which even on microscopic examination shows no tendency to form tumor osteoid or bone in its local growth or in its metastases", serves to separate fibrosarcoma of bone from chondrosarcoma and osteogenic sarcoma.

Medullary fibrosarcoma of bone originates in the connective-tissue elements of the bone marrow. According to Dahlin, most bone fibrosarcomata arise in either the medullary or the cortical regions; he found no definite instance of a "periosteal fibrosarcoma" in his series. Fibrosarcoma of bone is less common than chondrosarcoma or osteogenic sarcoma; fibrosarcoma occurs chiefly in the third and fourth decades although the tumor has been reported in patients as young as four months[3] and as old as seventy-six years[9]. The femur and the tibia are the bones most commonly involved. Well differentiated fibrosarcoma shows a predilection for the long bones, but involvement of the skull, sacrum, pelvis, mandible, ribs, and scapula has been reported[6,15,16,17]. The writer has been unable to find a prior report of a well differentiated fibrosarcoma of the calcaneus in the literature.

Pain and swelling of the affected part are the usual presenting symptoms. If the lesion is present in a lower extremity, limp may be a prominent feature. A well differentiated fibrosarcoma grows slowly and usually the lesion is fairly well advanced when the patient first consults a doctor. Occasional instances of pathological fracture have been described[11].

The well differentiated fibrosarcoma is white or grayish white and firm or even collagenous in consistency. Microscopically the tissue has a benign appearance. The fibroblasts are elongated and spindle-shaped; they tend to be uniform in size and shape and are usually arranged in strands or loose whorls. Only an occasional mitotic figure may be seen. A considerable amount of intercellular collagen is present. The benign histological appearance of these tumors belies their malignant behavior.

The prognosis of a well differentiated fibrosarcoma of bone is good if the lesion is completely excised. A recurrent lesion must be carefully compared with the original lesion. Should an increasing degree of anaplasia be evident, amputation is indicated. Metastases are unlikely to occur so long as representative sections from the lesion show a high degree of differentiation. Roentgen therapy is of no value.

SUMMARY

A patient is reported who had a well differentiated fibrosarcoma of the calcaneus treated by extraperiosteal resection of the bone two years after the onset of symptoms. He has now been followed for five years since operation with no evidence of local recurrence or metastasis. The clinical, roentgenographic, and pathological features of well differentiated fibrosarcoma of bone are described.

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Ossification of the Posterior Aspect of the Elbow

Two Cases

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Heterotopic ossification of the elbow, in which the process was confined entirely to the posterior aspect of the joint, was observed in two patients. Three elbows were involved. The development of this disorder was apparently initiated by trauma, without fracture or dislocation, by immobility, and by reinjury. The successful surgical management of this condition is reported in this paper.

Case 1. A garage foreman, thirty-six years old, was admitted to some other hospital on November 29, 1957, with an acute manic reaction of a manic-depressive psychosis. Soon after admission his mental status rapidly worsened, and his general condition became so serious that he was administered the last rites of his church. For the next ten weeks his course vacillated from relative calm to severe uncontrollable mania requiring arm and body restraints. After a two-month period of treatment with electric shock, sedatives, and phenothiazine compounds, in a sudden recurrence of mania, the patient demolished his bed and tried to knock down the door to his room. He was constantly restrained by forearm cuffs during periods of mania, and we believe it reasonable to assume that attempts to flex the elbow against the cuff caused pressure on the olecranon area This pressure, although intermittent, was forceful and repeated for many weeks.

Both elbows became tender and swollen soon after the onset of mania and were treated initially by moist dressings, followed a week later by hydrotherapy and exercise; nevertheless, the elbows stiffened. One month after the onset of psychosis, roentgenograms showed heavy soft-tissue calcification about the posterior aspects of both elbows (Figs. 1-A and 2-A).

The patient's mental status had improved by the fourth month, and he required no further treatment. His right elbow had no motion in flexion and extension; it was fixed at an angle of about 130 degrees. There was pronation to 45 degrees and supination to 20 degrees. Motion of the left elbow was from 90 degrees to 105 degrees with full pronation and supination. Roentgenograms showed a mass of bone along the posterior medial aspects of both humeri, extending to the ulna. The joint surfaces of both elbows were well preserved (Figs. 1-B and 2-B).

Surgery was performed on the left elbow four and one-half months after the onset of psychosis. A single longitudinal incision was made along the medial aspect of the elbow. After dissecting the ulnar nerve free, the medial aspect of the distal triceps was delineated and retracted laterally and posteriorly without disturbing the insertion. The humerus was thus exposed from behind and a smooth mass of bone, measuring four by two by one-half centimeters, was found attached to the humerus. This mass caused mild deepening of the groove for the ulnar nerve, extended into the olecranon fossa, and limited extension. This new bone was removed with an osteotome, most portions separating rather easily by prying. The range of motion in extension was thus improved but not complete.

Through the same incision the anterior aspect of the elbow was exposed by incising the fibrous tendon of origin of the flexor muscles at the medial epicondyle. The capsule was slightly thickened, the articular cartilage appeared normal, and the joint contours were not distorted. The anterior capsule was then excised, resulting in a wider range of motion. Complete extension was then blocked by impingement of the olecranon in its fossa; consequently, the fossa was deepened and the tip of the olecranon excised without disturbing the triceps tendon. There was then a full range of motion without tension. The ulnar nerve was anchored between the superficial and deep fascia anterior to the medial epicondyle.

Postoperatively, the elbow was splinted at 90 degrees for three weeks. Physical therapy was given, consisting in active range-of-motion exercises, progressive muscle-resistance exercises, and whirlpool treatments. Prednisone was administered, five milligrams three times a day for one month.

The right elbow was first operated on seven weeks after the left, or about six and one-half

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Left elbow one month after onset of psychosis.
Fig. 1-B: Left elbow four months after onset of psychosis.

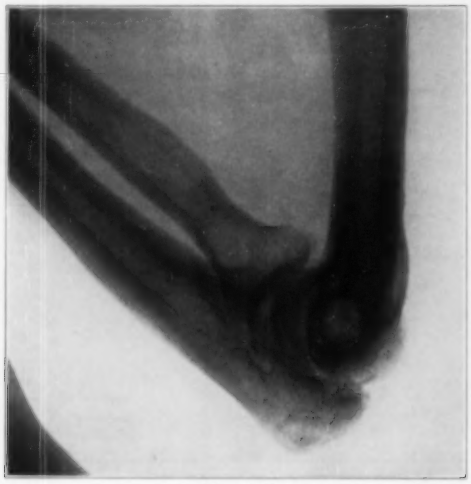

FIG. 1-C

Left elbow twenty-two months after surgery. The small amount of soft-tissue calcification seen had not changed in the five months preceding this final roentgenogram.

months after the onset of psychosis. Since the mass of so-called new bone in the right elbow was more extensive than that in the left and extended more toward the lateral aspect, it was felt necessary to expose the entire posterior portion of the humerus (Fig. 2-B). A single longitudinal incision was made along the medial aspect of the elbow. The distal triceps fascia and tendon were incised in a U-shaped flap, the base being at the olecranon. The triceps muscle was detached from its insertion and retracted proximally. The new ossification was about five by three by one-half centimeters, extended across the width of the humerus, and was united solidly to the olecranon. It completely encased the ulnar nerve for about three centimeters. The nerve was exposed proximal and distal to this incarceration and the roof of bone over the nerve was carefully removed with osteotome and rongeur. This mass of bone did not separate easily from the humerus, as it did in the left elbow, and removal did not improve motion.

The anterior aspect of the joint was exposed through the same incision. After the medial border of the brachialis muscle had been delineated, a periosteal elevator was passed between the muscle and humerus, elevating and retracting the muscles and overlying neurovascular structures anteriorly and laterally. Inspection showed no abnormalities other than a slight diminution in

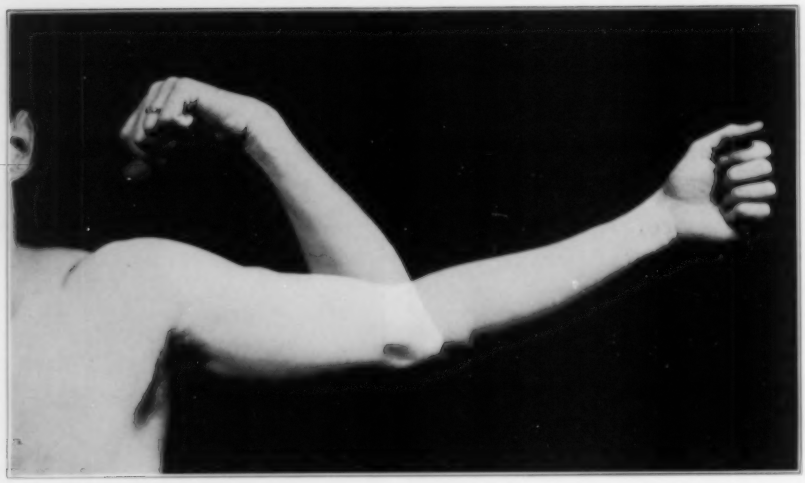

FIG. 1-D

Motion in left elbow twenty-two months after surgery.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 1. Right elbow one month after onset of psychosis.
Fig. 2-B: Right elbow four months after onset of psychosis.

luster of the articular cartilage and slight capsular thickening. Anterior capsulectomy resulted in improved motion. The tip of the olecranon was then excised and full motion without resistance was obtained. Fifty milligrams of hydrocortisone acetate and 150 turbidity reducing units of hyaluronidase were instilled into the joint. The first five days after surgery the patient received 100 milligrams of hydrocortisone (intramuscularly) daily, followed by a three-week regimen of prednisone.

Immediately after operation no ulnar-nerve function could be demonstrated. The elbow was splinted at 90 degrees for three weeks, after which time active range-of-motion exercises, strengthening exercises against resistance, and whirlpool treatments were begun. The patient was discharged from the hospital and returned to his occupation about two and one-half months after the second operation, but confined his activities to light work for several more weeks.

The patient was carefully re-evaluated seven months after this last operation. He was employed as a body and fender repairman but was not working efficiently because of the impaired right ulnar nerve and limited motion of the right elbow. Flexion and extension were from 70 to 100 degrees. Crepitation was mild and a solid block to extension was apparent (Fig. 2-C). Ulnar-nerve

FIG. 2-C

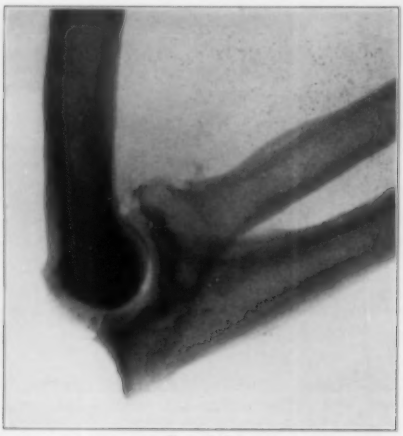

FIG. 2-D

Fig. 2-C: Right elbow seven months after first operation.
Fig. 2-D: Right elbow twelve months after second operation. The small amount of soft-tissue calcification seen had not changed in the five months preceding this final roentgenogram.

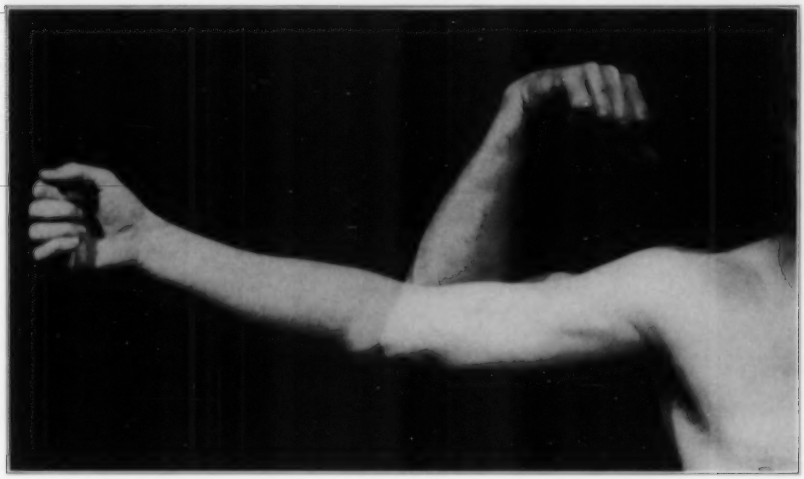

FIG. 2-E

Motion in right elbow twelve months after the second procedure.

function was about 40 per cent of normal. The left elbow showed nearly full flexion and extension to 165 degrees.

The right elbow was again operated on February 24, 1959, eight months after the first procedure. The same single longitudinal medial incision was used. The ulnar nerve was found to be bound by scar tissue in the region of the anterior aspect of the tip of the medial epicondyle. There was no neuroma. Scar tissue about the nerve was excised and retracted forward. The triceps muscle was delineated along the medial aspect and dissected free from the underlying humerus. It was then retracted posteriorly and laterally, exposing the olecranon fossa and the posterior aspect of the humerus. The insertion of the triceps was not disturbed. Two excrescences of bone were removed from the olecranon fossa and the olecranon process was shortened. There was no improvement in the range of motion. The flexor muscles were then detached from the medial epicondyle and the joint exposed anteriorly. The joint surface again appeared to be normal. The anterior capsule had re-formed and was slightly thickened. This was removed, and full extension was then possible. The arm was splinted in full extension for two and one-half weeks and then the patient was started on the same physical therapy program as before. At five weeks there was a range of motion from 90 degrees to 170 degrees. He returned to work one and one-half months after surgery. At his last check-up, one year after the last operation, the patient was employed full

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2. Left elbow two and one-half years after cholecystectomy and just prior to elbow surgery.
Fig. 3-B: Left elbow ten months after surgery.

FIG. 3-C

Range of motion ten months after surgery.

time as a body and fender repairman and was able to use power tools and heavy tools, such as an eight-pound sledge hammer.

The patient's only complaint was mild tingling in the right little finger. There was neither functional impairment nor objective evidence of neuropathy. Flexion-extension motion was from 60 to 165 degrees on the right and 50 to 165 degrees on the left. Although pronation and supination were limited by 40 per cent on the right, they were normal on the left. There was mild painless bilateral crepitation. Muscles of both elbows and hands were very powerful (Figs. 1-C, 1-D, 2-D, and 2-E).

CASE 2. A man, fifty-seven years old, was admitted in November 1956. A diagnosis of gallstones and obstructive jaundice was made and on December 6, 1956, cholecystectomy was performed. The patient bled internally after surgery and required two additional abdominal operations. His course was further complicated by pneumonia, atelectasis, gastro-intestinal hemorrhage, and superficial phlebitis of both greater saphenous veins which required bilateral ligation. The patient was very ill and semicomatose for two or three weeks; it was not until a month after surgery that he began to talk and to move about in bed. Fifty pints of blood had been administered and many more liters of intravenous fluids. On the nineteenth postoperative day, a venous cut-down was performed in the left antecubital fossa. Both before and after this cut-down, the extremity was maintained on an arm board. The cut-down site was soon infected and the entire arm

became edematous and indurated. This condition, diagnosed as superficial cellulitis, was treated with warm moist packs for nearly three months. The infection was thought not to extend beneath the deep fascia.

A program of physical rehabilitation, consisting in general muscle exercise and gentle active and passive range-of-motion exercises of all joints, was begun six weeks after cholecystectomy. The patient recalled that on one occasion the elbow was forcefully manipulated in an attempt to restore motion.

Three months after surgery there were edema, stiffness, and weakness of all extremities; it was not until the seventh month that the patient could walk well with a cane. The elbow became ankylosed at 135 degrees. Operative correction was advised but the patient was reluctant to have further surgery.

Two and one-half years after this episode, examination demonstrated the elbow fixed at 135 degrees of extension. Pronation and supination were normal. There was hypesthesia in the area of the ulnar-nerve distribution, but good motor function. Roentgenograms showed a mass of bone on the distal posteromedial aspect of the humerus which joined the olecranon to the humerus. The joint space was well preserved and there was no distortion of the joint contours (Fig. 3-A).

Surgery was performed through a medial longitudinal incision. The ulnar nerve was freed from its bed. The heterotopic bone, which was exposed by retracting the distal triceps laterally and posteriorly, extended to the groove for the ulnar nerve and caused deepening of the groove. It was very solidly attached to both the humerus and the olecranon and did not separate easily. The joint cartilages of the ulna, radius, and humerus appeared smooth but had lost their normal gloss and were mildly discolored with hemosiderin. A small portion of the tip of the olecranon was then excised without detaching the triceps. There was only moderate improvement in the range of motion. The brachialis muscle was then retracted anteriorly and laterally, the anterior aspect of the joint was entered, and the slightly thickened anterior capsule was excised. This resulted in full motion. The ulnar nerve was anchored between superficial and deep fascia anterior to the medial epicondyle. Fifty milligrams of hydrocortisone acetate and 150 turbidity reducing units of hyaluronidase were instilled into the joint. One week after surgery the patient was given cortisone (orally), twenty-five milligrams four times a day for three weeks.

The elbow was splinted at 90 degrees for two weeks after which physical therapy, consisting in range-of-motion and progressive muscle-resistance exercises and whirlpool therapy, was begun. Active exercise was difficult at first because the patient could not contract either the biceps or the triceps separately. Efforts to flex or extend the joint resulted only in contraction of both muscles simultaneously, without production of motion. To help improve muscle function, the patient was instructed to hold a five-pound weight and contract his biceps and then his triceps against the resistance. A week later a ten-pound weight was held. Care was taken that these weights were not used as a stretching device.

The patient returned to work as a part-time bartender about four months after the elbow surgery. His return to work was not delayed by the elbow surgery, but by repair of an abdominal incisional hernia two months after the elbow operation.

He was last seen in February 1960, eleven months after surgery. There was no pain, but he was conscious of a slight disability from the limited extension. Tingling in the area of the ulnar-nerve distribution was the same as before surgery. Pronation and supination were full. Flexion-extension motion was from 45 to 160 degrees. There was no swelling or crepitation. Strength of the elbow and hand was excellent and sensation was normal (Figs. 3-B and 3-C).

DISCUSSION

Etiology

Heterotopic ossification around joints is not an unusual observation. Normally, this condition is caused by a rather severe injury such as fracture, dislocation, extensive damage to the capsule, or damage to the ligaments and overlying muscles. Such severe trauma with necrosis of tissue, especially muscle, along with hematoma, and elevation of periosteum, is classically regarded as being prerequisite for periarticular ossification [13,16,20].

Extensive areas of heterotopic ossification about joints are occasionally seen accompanying poliomyelitis [4,6,12], paraplegia [1,15], and hemiplegia [10]. Apparently, in such instances, a causal relationship to trauma is remote, but certainly such patients are frequently subjected to stretching exercises in an attempt to prevent or overcome deformity.

The etiological factors involved in these cases have not been definitely established. There were several common features which seem important: both patients were critically ill for several weeks; immobilization of the involved elbows was present to some degree; and the elbows suffered reinjury to some extent.

The cases were dissimilar in the degree of initial trauma. As previously noted, the maniacal patient suffered early injury to the elbow and, although neither fractures nor dislocations were found, the elbows were swollen and painful soon after admission. On the other hand, there was no record or evidence of initial physical trauma to the elbow of the second patient. The diffuse, chronic cellulitis at the venous cut-down in the left antecubital area was probably significant.

Johnson reported four cases of localized ossification about joints in which gross trauma was not a factor. Elbows, as well as other joints, were involved in four instances. ". . . . three of these patients had severe burns. However, in one the areas of excessive ossification were not even superficially burned and in the other two the joint capsules and deep muscles were not considered to be directly damaged. In the fourth case trauma was never noted and a neurological lesion of the type causing trophic changes, as in paraplegia, was not present." (The patient was comatose a few weeks.)

Johnson found that the common features of the cases he reported were relative immobility and a precarious general condition. He felt that, ". . . the tissues evidently were in no condition biochemically or biophysically to resist even slight injury", which might occur when burn dressings were changed while the patient was under sedation, or when a patient was given routine nursing care which might include stretching and massaging by well meaning persons.

Evans and Smith reported on twenty cases of demonstrable skeletal alteration. In eleven patients changes that developed in the pericapsular structures included pericapsular calcification and heterotopic para-articular ossification. They noted, "The proximity of the involved joint to the area of burn is not consistently a factor in the production of heterotopic bone." In the unburned elbow of one patient there developed extra-articular fusion; the other elbow, however, showed soft-tissue contracture from an adjacent burn, but not a skeletal lesion. These authors regarded the severely burned patient to be "constitutionally susceptible to trauma, and it may be that the repeated minor trauma of routine handling or dressing change is a sufficient incitant."

Treatment

It is often observed that if this heterotopic bone is removed before maturation has occurred, there is a strong tendency for recurrence. Accordingly, it is universally advised that surgery be delayed until the bone becomes dense, consolidated, well demarcated, and new-bone formation has ceased [3,16,17,18,20]. There are also reasons for not delaying surgery too long. All periarticular structures accommodate to the limited motion and deformity by shortening, loss of elasticity, replacement fibrosis, and adhesions. There is decreased range of contractility of muscles and soft-tissue limitation of motion. Intra-articular adhesions may consolidate and cartilage degenerate. In this connection it is interesting to note that the best result in the three elbows reported here was obtained in the case in which the time interval from onset of disorder to surgery was two and one-half years—an interval four times longer than for the other elbows.

These elbows were operated on at five, six and one-half, and twenty-seven months after the onset of the disorder. There was ankylosis in two, and only slight motion in the third. In all three the articular cartilage appeared essentially normal except for lack of luster and, in one case, mild yellowing.

Both arthroplasty and the more limited procedure of excising the new bone were considered. It was felt that since roentgenograms showed the joint space to be well preserved, and the heterotopic bone to be localized posteriorly, the more conservative procedure should be used. If this failed, arthroplasty could always be performed as a second procedure. The first patient helped with this decision by saying he could not return to his former occupation with an unstable elbow which might result from arthroplasty. Others have treated somewhat similar lesions of the elbow with this less radical operation, confining the surgery to those bone and soft-tissue elements that directly limited motion [2,5,11,21].

In each case the new bone was situated on the posteromedial aspect of the humerus and the surgical approach was planned to provide exposure not only of the bone posteriorly but also of the anterior capsule. The bone in two elbows could be adequately exposed and excised merely by retracting the triceps tendon and muscle laterally without actually disturbing its continuity. The exception was the second elbow where the mass was so wide that it seemed better to expose the entire posterior aspect of the humerus by incising the triceps fascia in a U-shaped line based distally, giving adequate exposure. This more traumatic procedure had the poorest result and reoperation was required, but even then the motion finally attained was the least. Since this elbow was the most severely involved no conclusions as to the influence of this exposure can be drawn.

Anterior exposure of the elbow through the same incision was performed in each case for the purpose of anterior capsulectomy. This was facilitated in two operations by incising the tendon of origin of the flexor muscles just distal to the medial epicondyle. Only enough fibrous tissue was left on the medial epicondyle to expedite repair. In the other two cases this was accomplished by merely retracting the brachialis and overlying biceps together with vessels and nerves anteriorly and laterally. This method is less traumatic and is adequate for this particular procedure. When the anterior muscles are relaxed by flexing the elbow, the anterior capsular space can be well visualized.

The best result was obtained in the last case reported. This was the only instance in which the joint was visualized merely by retraction of the triceps posteriorly and the brachialis anteriorly without incising muscle or tendon. The results might have been better in the other elbows had this approach been used.

Physical therapy, consisting mainly in active exercise for strength and range of motion and whirlpool, was begun on the day the splints were removed. Motion was slow to return and both the patients and the physicians had to guard against undue pessimism. Because of this delay, the patients required daily encouragement to continue the prescribed activities. It was always a temptation in such instances for physicians, therapists, and the patient himself to help the elbow by forceful passive stretching. The orthopaedist must be aware of this temptation and be constantly on the alert to prevent its indulgence.

Evidence in the literature regarding the use of hyaluronidase and the adrenal cortical steroids to improve motion after joint procedures is not conclusive and is sometimes contradictory [7,8,9,14,19,22]. However, either one or both medications were used in all three cases. The steroids did not adversely affect the mental status of the first patient.

In each case the ulnar nerve was transplanted anteriorly because the new-bone formation involved the ulnar groove and it was feared that fibrosis following surgery would infiltrate this area. The first extremity did not exhibit nerve disability either before or after surgery. The second had no ulnar difficulty before surgery but nearly total loss of function after surgery. It will be recalled that this ulnar nerve had been encased in bone for a length of three centimeters. After

reoperation and removal of scar tissue about the nerve, there was gradual return of function until there was finally normal strength with only slight paresthesia. The third extremity exhibited normal muscle power but there was hypesthesia in the ulnar-nerve distribution. After surgery this strength was noted to be excellent, but the hypesthesia persisted.

SUMMARY

This paper reports three cases of heterotopic ossification confined to the posterior aspect of the elbow, with severe limitation of flexion and extension in one and ankylosis in the others. Certain etiological factors are considered and comparisons are made with similar, but not identical, cases reported by others. In all three cases treatment consisted in surgical excision of the posterior mass of bone and anterior capsulectomy. Final motion obtained in flexion and extension was 50 to 165 degrees, 60 to 165 degrees, and 45 to 160 degrees.

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Dislocation of the Hip Secondary to Trochanteric Decubitus

A Complication of Multiple Sclerosis

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Although septic dislocation of the hip has been mentioned as a possible complication of trochanteric decubitus ulcer[1], no report has been found in the literature indicating that this may be a relatively frequent and easily overlooked complication, particularly in patients with advanced neurological diseases who are receiving custodial care in large institutions for chronic disease.

This is the report of five patients with pyarthrosis and dislocation of the hip caused by the extension of infection from a trochanteric decubitus ulcer. These cases were encountered during the last three years in a large hospital for chronic disease. All the patients were suffering from long-standing, extensive neurological disease. Four had multiple sclerosis; one had incurred transection of the spinal cord at the level of the eighth thoracic vertebra and a right hemiplegia in an automobile accident eight years previously. In one patient there were bilateral dislocations of the hip, the second occurring three months after the first.

Until dislocation occurred, in no instance were there any obvious local changes to indicate the malignant character of the septic process affecting the hip joint. All the trochanteric decubitus ulcers were small and innocuous in appearance and had been present for one or more years. The first presenting sign was high fever accompanied by malaise. The cause of the fever was invariably sought elsewhere. All patients had indwelling urethral catheters because of neurogenic malfunction of the bladder. Consequently, cystitis or pyelonephritis was initially considered to be the cause of the acute illness. None of the patients had any pain from the progressive destruction of the hip joint and the external appearance of the trochanteric decubitus ulcer did not change as the infection involved the underlying joint capsule. Roentgenograms of the hip during the first few weeks of the invasive process were usually negative. It is easy to see how the physicians in charge failed to make the proper diagnosis for many weeks after the onset of acute sepsis.

During the weeks of slow and subversive invasion of the hip joint, the patient's general status steadily declined. The correct diagnosis was made in each instance either as the result of the dramatic appearance of the femoral head in the decubitus ulcer or by roentgenogram (Figs. 1-A and 1-B).

REVIEW OF CASES

Data concerning age, sex, and duration of illness are summarized in Table I. The ages of these patients ranged from twenty-seven to fifty-nine years. All patients were known to have had neurological disease for eight years or more; all were severely disabled and confined to a bed and wheel chair. In three of the patients multiple small decubitus ulcers overlying bone prominences about the hip had been present for years without serious complication until the dislocation of the hip.

TREATMENT AND SUBSEQUENT COURSE

In each case treatment consisted in resection of the proximal three or four

inches of the femur and débridement of necrotic tissue (Table II). All wounds were left open. The patients were kept on a Stryker frame to facilitate care of the skin, but no attempt was made to immobilize the resected hip. Antibiotics were administered according to the results of wound-culture and drug-sensitivity tests. Close attention was given to the patient's fluid and nutritional intake.

The first patient, Case 1, in this group did not improve after operation. Cellulitis and necrosis advanced proximally into the pelvis and distally into the thigh. A second débridement, one month after the first, did not alter her steady down-

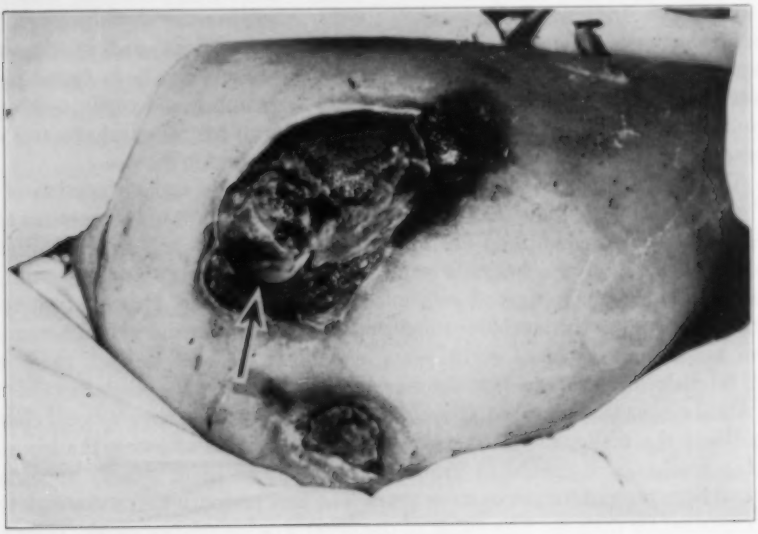

FIG. 1-A

Case 3. Photograph immediately after the appearance of the right femoral head (indicated by arrow) in the trochanteric wound. A sacral decubitus ulcer is also present.

FIG. 1-B

Roentgenogram at the time of the dislocation of the right hip.

FIG. 1-C

Photograph made after two operations for excision of the upper end of the right femur and excision of the upper end of the left femur. The right hip wound is healed. (This photograph was made six months after Fig. 1-A.)

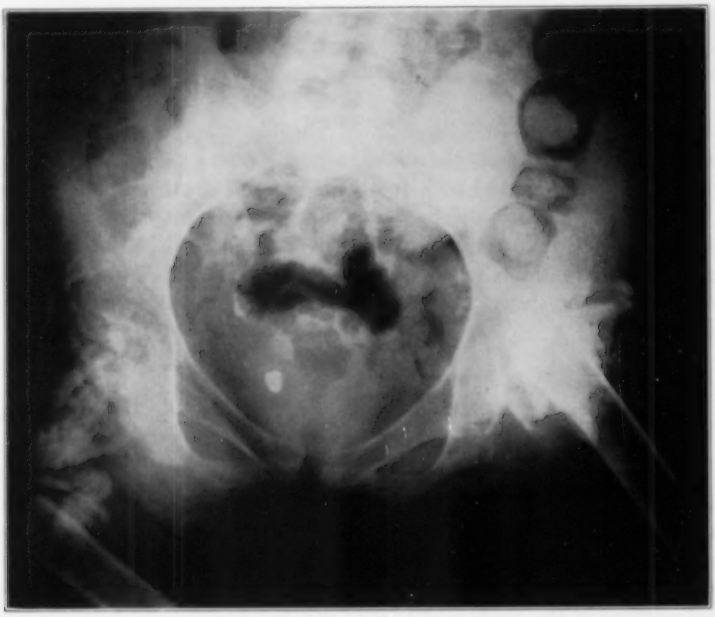

FIG. 1-D

Roentgenogram one year after bilateral resection of the upper end of the femur.

ward course; she died one month after the second operation.

The four other patients, including one with both hips involved (Figs. 1-C and 1-D), responded well to treatment. Their general condition improved steadily and their wounds gradually filled in from the bottom with granulation tissue. Three of the five wounds closed completely, one after a second operation. Another continued to drain because of low-grade osteomyelitis of the pelvis for the next

TABLE I

Case No.	Patient	Age (*Years*)	Sex	Diagnosis	Duration of Neurological Disease (*Years*)	Length of Time Since Patient Had Walked (*Years*)
1	R.B.	46	F	Multiple sclerosis	12	8
2	A.S.	31	F	Multiple sclerosis	12	4
3	E.N.	38	F	Multiple sclerosis (bilateral dislocation)	22	14
4	N.P.	27	M	Multiple sclerosis	8	6
5	S.S.	59	F	Traumatic triplegia	8	8

two years, when the patient died of pyelonephritis. The fifth wound was not quite closed when the patient died four months after operation. It is noteworthy that only one of these four patients was discharged home. The other three died from causes unrelated to their hip disease four months, five months, and two years after resection of the femur.

DISCUSSION

In a review of 1,072 cases of multiple sclerosis over a twenty-two-year period decubitus ulcer was reported as a frequent cause of death [2]. Septic dislocation of the hip from a trochanteric decubitus ulcer was apparently not noted. Most of the patients died in their own homes or in nursing homes where roentgenograms could not be easily obtained. It is possible that dislocation of the hip may have occurred in some of these patients without the knowledge of the attending physician.

SUMMARY AND CONCLUSION

Six pathological dislocations of the hip in four patients with multiple sclerosis and in one patient with traumatic triplegia are presented. All occurred as a result of pyarthrosis caused by extension from a long-standing, infected trochanteric decubitus ulcer. In all, recognition of the serious infection affecting the hip joint was delayed greatly because of the patient's neurological disease with paralysis and lack of sensation.

Vigorous surgical treatment, antibiotic medication, and general supportive measures resulted in the healing of four of the wounds and residual osteomyelitis in one. One patient died of septicemia.

In four of the five patients there was an excellent local response to treatment, but all save one of these patients died within two years of the operation because of other complications of their neurological disease. Earlier recognition of the possible malignant nature of penetrating trochanteric decubitus ulcers should result in earlier surgical treatment and reduced morbidity and mortality. Closure of decubitus ulcers should be undertaken early, before the stage of invasion. If healing of these decubitus ulcers can be achieved after marked destruction of the

TABLE II

POSTOPERATIVE RESULTS

Case No.	Patient	Interval between Onset of Fever and Recognition of Hip Involvement (*Months*)	Treatment	Result
1	R.B.	2	Two resections of upper end of femur and débridement, one mo. apart	Patient died of septicemia one mo. after second operation
2	A.S.	2	Resection and débridement; wound closure ten wks. later	Had small sinus which healed after eight mos.
3	E.N. (right hip)	2	Two resections with débridement	Wound healed two mos. after second resection
	E.N. (left hip)	2½	Resection and débridement	Sinus persisted; patient died of pyelonephritis two yrs. later
4	N.P.	1½	Resection and débridement	Wound healed five mos. later, a few weeks prior to death from pyelonephritis
5	S.S.	3	Resection and débridement	Wound had healed, except for one centimeter of superficial area, when patient died of unrelated cause four mos. after operation

hip joint, it is obvious that appropriate vigorous treatment will be successful at this early stage, when the patient is in better general condition.

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Pigmented Villonodular Synovitis with Invasion of Bone

Report of Six Cases *

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Pigmented villonodular synovitis, tenosynovitis, and bursitis are well known and not uncommon. Erosion and invasion of adjacent bone in the hands and feet from lesions of the tendon sheath are also well known in this disease, but invasion of bone from intra-articular synovial lesions has not been observed frequently and few cases have been recorded. Six such cases, three of the knee and three of the hip, are here reported, all with definite roentgenographic changes and characteristic microscopic findings. No case with invasion of bone about the knee has been found reported in the literature.

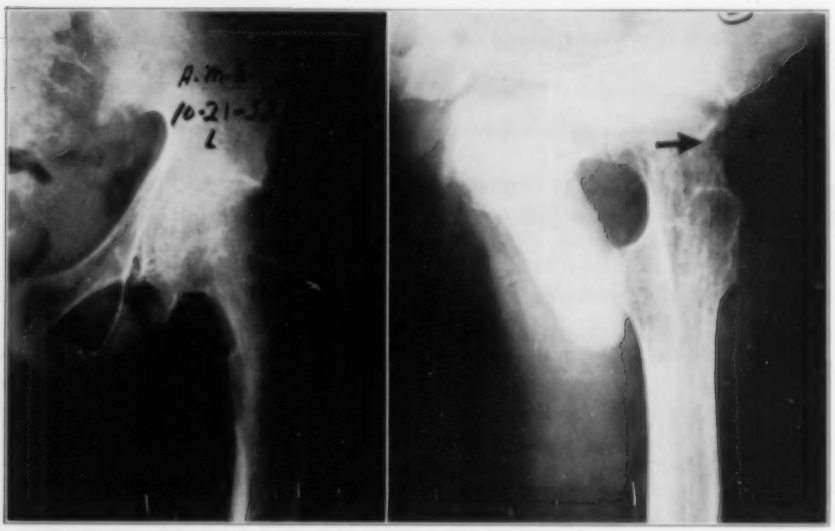

Fig. 1-A

Case 1. Roentgenograms show multiple cystlike areas in the femoral head and acetabulum. In the lateral roentgenogram, a one-centimeter area of bone destruction on the anterior surface (arrow) can be seen.

CASE REPORTS

Case 1. A forty-year-old male Mexican was first seen on October 21, 1952, with a complaint of intermittent pain in the left hip of two years' duration. There was no history of injury. Three months before admission, the pain, which was present with use, but not at rest, forced him to quit work. Physical examination revealed limited motion and a few degrees of flexion contracture, and some discomfort on forced rotation of the left hip, as well as mild tenderness over the anterior aspect of the joint. Roentgenograms revealed several small cystic areas in the femoral head and acetabulum; there was also an irregular, lytic lesion, one centimeter in diameter, in the subcapital area in

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, May 31, 1960.

the anterior portion of the neck of the femur. There was some narrowing of the joint space (Fig. 1-A).

An arthrotomy was performed on November 19, 1952. The joint contained yellowish brown fluid and one free nodule of reddish brown tissue, 1.5 centimeters in diameter. There was diffuse involvement of the synovial membrane, which was thickened and reddish brown. Synovectomy was done and the lesion in the femoral neck was curetted. Microscopic sections of both the synovial membrane and the lesion in the femoral neck revealed pigmented villonodular synovitis.

The patient received postoperative radiation therapy. In October 1953, he was free of pain and had been working regularly with excellent, painless motion of the hip. In August 1955, he was still working, but had a limp and some limitation of hip motion. In November 1956, he was still working, but he had a great deal of hip pain by mid-afternoon every day, more limitation of hip motion, and a severe limp. Roentgenograms revealed narrowing of the joint space, marginal lipping, and additional lesions in the femoral neck (Fig. 1-B). Arthrodesis was performed in January 1957, with solid ankylosis resulting. When last seen in April 1960, the patient was working regularly and had no complaints. Roentgenograms revealed no evidence of extension of the lesions in bone.

FIG. 1-B

Roentgenogram made four years after those in Fig. 1-A shows further bone invasion, especially of the femoral neck. There are also narrowing of the joint space and marginal lipping.

CASE 2. A white man, forty-five years old, had injured his right knee eighteen years before, while playing professional football. He had had pain in the knee off and on since. In February 1953, examination revealed a cystic lesion in the upper portion of the tibia (Fig. 2-A). Biopsy of the bone lesion was done. Only a small piece of tissue was obtained and a microscopic diagnosis of subacute and chronic inflammation was made. Thereafter, he continued to have increasing discomfort and swelling of the knee. When he was first seen by the author, in February 1956, there was marked swelling of the knee and some increased local heat; knee motion was from 175 to 80 degrees. Roentgenograms revealed a large cystlike area in the upper part of the tibia and a smaller cystlike area in the lateral femoral condyle (Fig. 2-B). Aspiration of the knee yielded viscid serosanguineous joint fluid.

Arthrotomy on March 3, 1956, revealed a markedly thickened, hypertrophic, reddish brown synovial membrane. A synovectomy, as complete as possible, was performed, and an incision was then made over the upper part of the tibia. When the cystic area was opened, the same dark reddish brown hypertrophied synovial membrane-like tissue and sanguineous fluid were found. The cavity, which was extensive, was curetted and found to communicate directly with the knee joint in two areas: one in the anterior intercondyloid fossa; the other at the chondro-osseous junction at the posteromedial joint margin of the tibia. Following curettage, the large cavity was filled with

FIG. 2-A

Case 2. Roentgenograms show a large cystlike area of bone destruction in the upper portion of the tibia.

FIG. 2-B

Roentgenograms made three years later show extensive bone involvement of the upper portion of the tibia and a destructive lesion of the lateral femoral condyle (arrow).

bank-bone grafts. An additional area of bone involvement was present in the lateral femoral condyle, and a small direct opening into this was found in the posterolateral aspect at the chondro-osseous junction. This area also was curetted after enlarging the opening; similar tissue and fluid were found. The roentgenograms had suggested a small area involving the patella, but no direct extension into the patella could be demonstrated, although some marginal erosion of the articular cartilage was seen. Nothing was done to the patellar lesion; the femoral cavity was filled with small bone chips. After operation a toe-to-groin cast was applied. Microscopic studies revealed pigmented villonodular synovitis, both in the synovial membrane and in the tissue removed from the tibial and femoral areas.

The cast was worn for three months, and five months after operation the patient was permitted some protected weight-bearing with crutches; after six months, he used a cane. His operative wounds healed *per primam*, and he had no significant postoperative discomfort. Aspiration of the knee subsequent to surgery was not necessary.

Postoperative roentgenograms revealed the cavities to be filling in; however, there were areas

FIG. 2-C

Roentgenograms, made four years after synovectomy and the insertion of bone grafts into the tibial and femoral lesions, show some collapse of the medial tibial plateau.

of rather pronounced decreased density in the large tibial cavity, suggesting possible recurrence of the process. Radiation therapy was considered, but not given for fear of impairing the blood supply and impeding incorporation of the bone grafts. Gradual collapse of the medial tibial plateau had occurred where the bone was thinned and weakened by the cystlike lesion. The patient was last seen and examined four years after surgery, at which time he had no complaints except some occasional aching after prolonged walking. He was active and working regularly. Knee motion was from 175 to 95 degrees. Roentgenograms then revealed further healing within the cystic areas, as well as some collapse of the medial tibial plateau (Fig. 2-C).

CASE 3. A white man, forty-four years old, admitted to the hospital in July 1957, complained of gradually increasing pain in the right hip, with radiation to the right knee, of three years' duration. There was no history of injury. The pain was dull and intermittent, but always present with activity and motion of the hip. There was stiffness and discomfort after inactivity and rest. The physical examination revealed a limp, mildly limited motion of the right hip, and slight pain on forced motion of the hip. Laboratory studies were not unusual. Roentgenograms made on July 12, 1957, revealed a rather large, lytic lesion in the anterior subcapital region of the neck of the femur, similar areas in the superior lateral margin of the acetabulum, and some apparent calcification in the capsule superiorly. There also were lytic areas in the inferior and medial portions of the acetabulum (Fig. 3-A). A preoperative diagnosis of pigmented villonodular synovitis was made.

At operation on July 30, 1957, excess free fluid was noted on opening the capsule. The fluid was dark brown, and contained several free, small, soft bodies which appeared to consist of coagulated mucinous material. The synovial membrane was thickened and dark reddish brown. This tissue was seen to extend into a small opening in the anterior aspect of the femoral neck and into the superior acetabular lesion. Synovectomy was done, combined with curetting of the lesions in the femoral neck and superior part of the acetabulum. Chips of bone, taken from the iliac crest, were placed in these areas.

The microscopic diagnosis of the synovial lesion and the tissue from the bone lesions was pigmented villonodular synovitis. The patient received radiation therapy in the spring of 1958. When last seen in April 1960, he had no complaints and was working regularly as a police patrolman. Roentgenograms at the last visit showed no significant changes from the initial pictures (Fig. 3-B).

CASE 4. A thirty-year-old white man was admitted on February 16, 1959, with a complaint of pain in the right hip. A large, arborescent, yellowish mass, which measured fifteen by ten centimeters and which was directly connected to the right hip joint, had been removed from the retroperitoneal area in 1953 at the Grand Island Veterans Administration Hospital in Nebraska. This had been variously diagnosed; first, as xanthoma or reticulum-cell sarcoma, but finally as pigmented villonodular synovitis. Thereafter, the patient progressed satisfactorily, with only occasional discomfort, until a week before admission to the hospital in February 1959, when rather severe

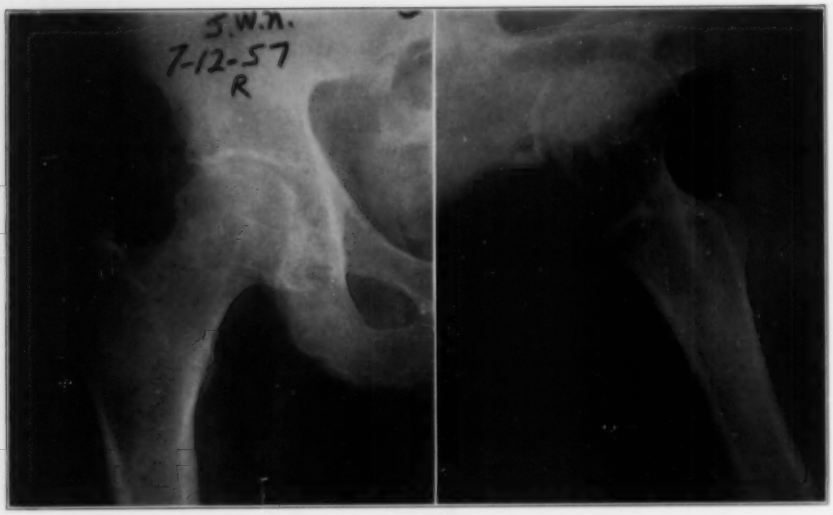

FIG. 3-A

Case 3. Roentgenograms show large cystlike areas of destruction in the femoral neck and acetabulum.

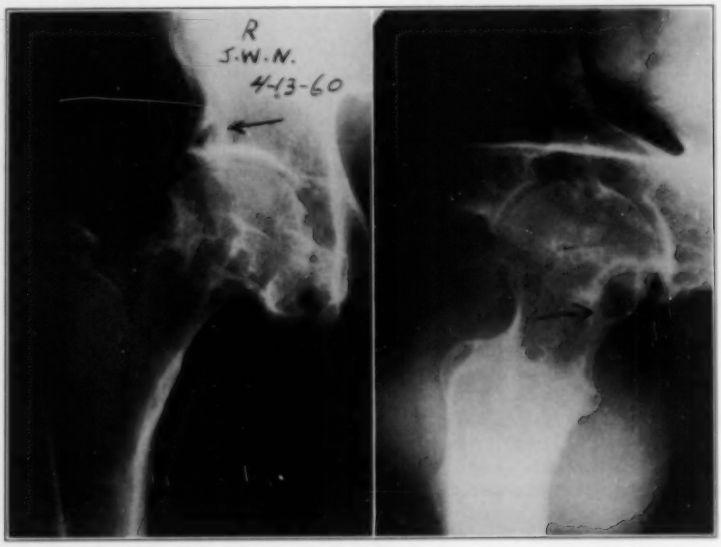

FIG. 3-B

Nearly three years after synovectomy, curettage of the lesion, and insertion of autogenous iliac chips. There is some evidence of repair in the lesions of the femoral neck and the acetabulum.

pain developed in the hip with use. He did not recall any injury, and had had no pain at rest. The physical examination revealed that he had a limp and some tenderness over the anterior region of the hip, but there was a good range of hip motion. There was a well healed surgical scar which extended from the right hip area up over the lower right part of the abdomen. Roentgenograms of the pelvis and right hip revealed a cystic area in the central portion of the acetabulum (Fig. 4-A). A preoperative diagnosis of pigmented villonodular synovitis was made.

At operation on March 31, 1959, an irregular, nodular, yellowish, soft tumor was encountered which extended from the hip joint into the pelvis and was estimated to measure eight by four by four centimeters. The intracapsular mass and most of the intrapelvic extension were removed, and a partial synovectomy was performed; but the hip was not dislocated for curetting the acetabu-

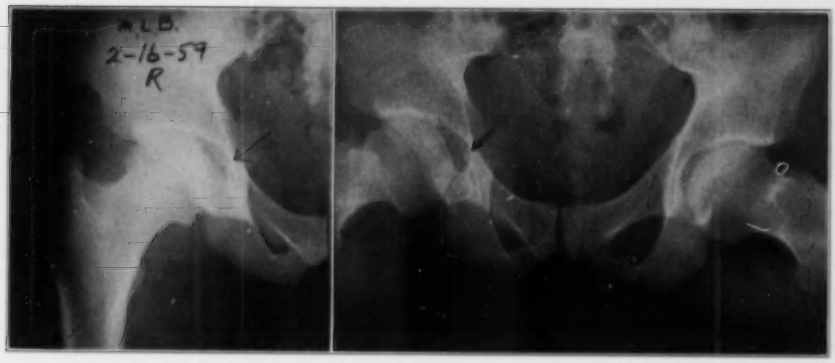

FIG. 4-A

Case 4. Roentgenograms show destructive lesion in the acetabulum (arrows).

FIG. 4-B

One year after partial synovectomy and removal of the intrapelvic extension of the lesion without curettage of the acetabular lesions. Lesions in the acetabulum appear to have enlarged.

lar lesion. The microscopic diagnosis was pigmented villonodular synovitis. Radiation therapy was given in April of 1959.

The patient was last examined on April 5, 1960, when he had no complaints and was working regularly. There was a good, painless range of motion; roentgenograms revealed some increase in the acetabular lesions (Fig. 4-B).

CASE 5. A white man, forty-five years old, was first seen on July 15, 1958, with complaints of pain and swelling of the right knee. He had sustained a twisting injury of the knee in December 1955, with subsequent swelling and some pain; but these symptoms had subsided within a few weeks, and he had had no further trouble of any consequence until about a year before being seen. He noted at that time, without any antecedent injury, the presence of some swelling and a small lump above the knee cap. This gradually enlarged, moved about, and tended to catch at times. There was also a gradual increase in swelling of the knee. Physical examination revealed a swollen right knee, with increased free fluid and what appeared to be a firm, movable mass in the suprapatellar area. There was some increased local heat, but no redness. Knee extension was complete; flexion was somewhat limited. There was no abnormal mobility, no quadriceps atrophy, and no limp. Aspiration of the knee yielded sixty cubic centimeters of reddish brown fluid; six days later, a similar amount was removed. Roentgenograms brought in by the patient, dated March 22, 1956, showed a small cystic area near the lateral margin of the patella visible in a tangential view (Fig. 5-A). A preoperative diagnosis of pigmented villonodular synovitis was made.

FIG. 5-A FIG. 5-B

Fig. 5-A: Case 5. Roentgenogram shows destructive area of the patella.
Fig. 5-B: Nearly two years after synovectomy and curettage of the lesion in the patella, roentgenograms show some evidence of repair of the lesion.

Arthrotomy on July 23, 1958, revealed bloody fluid and a diffuse hypertrophied, shaggy, yellowish brown synovial membrane. Invasion and partial destruction of the proximal portion of the anterior cruciate ligament had occurred. The ligament was partially excised, and synovectomy was done. On the lateral aspect of the patella at the chondro-osseous junction, the process had eroded and extended into the underlying bone. The involved bone was curetted.

The patient's postoperative course was satisfactory; he received no radiation therapy. The last examination, in April 1960, revealed some infrapatellar thickening, some quadriceps atrophy, and limited knee motion, from 170 to 105 degrees. There was no increased local heat and no abnormal mobility. He had no pain, but had to go up or down stairs one at a time. Roentgenograms showed some filling in of the patellar lesion (Fig. 5-B).

CASE 6. A Negro man, twenty-eight years old, was admitted on September 9, 1959, with complaints of rather marked pain and swelling in the right knee of three weeks' duration. He had had an injury to the knee in 1952, and an operation was performed at that time. The meager information available indicated that meniscectomy and partial synovectomy had been performed. After the procedure he was doing well until February 1955 when some pain and swelling of the knee developed. He quit barber training at that time because he could not stand for long periods. He had intermittent pain and swelling of the knee thereafter until the present episode, which was much more severe than any previous episode.

Physical examination revealed a well healed median parapatellar scar and marked swelling of the knee on both its anterior and its posterior aspects. There was evident increased free fluid and slight increased warmth, but no significant tenderness. Extension was present to 170 degrees and flexion to 75 degrees. There was no abnormal mobility.

Laboratory studies revealed no abnormalities. Aspiration of the knee yielded a brownish orange viscid fluid, which formed a yellowish foam on shaking the tube. Cultures of the fluid yielded no growth.

Roentgenograms revealed a fairly large, cystlike lesion in the upper portion of the tibia and multiple other small, punched-out, cystlike lesions in the upper portion of the tibia and in the femur (Fig. 6-A). A tentative diagnosis of pigmented villonodular synovitis was made.

Arthrotomy was performed on October 13, 1959, through a long anteromedial incision. Considerable brownish yellow viscid fluid was present, and the synovial membrane was hypertrophied, shaggy, and dark brown to yellow. A few small sessile yellowish nodules were noted. Synovectomy was done, and multiple small areas of bone invasion at the chondro-osseous margins of the patella, femur, and tibia were curetted. A pannus-like invasion, with direct erosion of articular cartilage of a striking degree, was seen on the margins of the femoral condyles (Fig. 6-B) and of the patella. Direct invasion into the anterior cruciate ligament, requiring partial excision of the ligament, was also noted. A small direct perforation of the upper part of the tibia in the anterior intercondyloid fossa was identified, and this connected with an expanded lesion in the upper part of the tibia, which was filled with the same brownish yellow synovial tissue. The opening was enlarged and the lesion was curetted. A second posteromedial skin incision was made, and further extensive involvement of the anserine bursa and portion of the medial hamstring tendons was found. As much as possible of this involved tissue was removed. Since the posterior portion of the joint was greatly involved, it was decided to postpone exploration of this until a later date. On December 15, 1959, the posterior compartment of the joint was explored and found to be extensively involved. The synovial membrane was markedly thickened, shaggy, and yellowish brown. Several small areas of bone erosion and one large area just above the lateral femoral condyle were found. The posterior

FIG. 6-A

Case 6. Roentgenograms show extensive involvement of both the tibia and the femur.

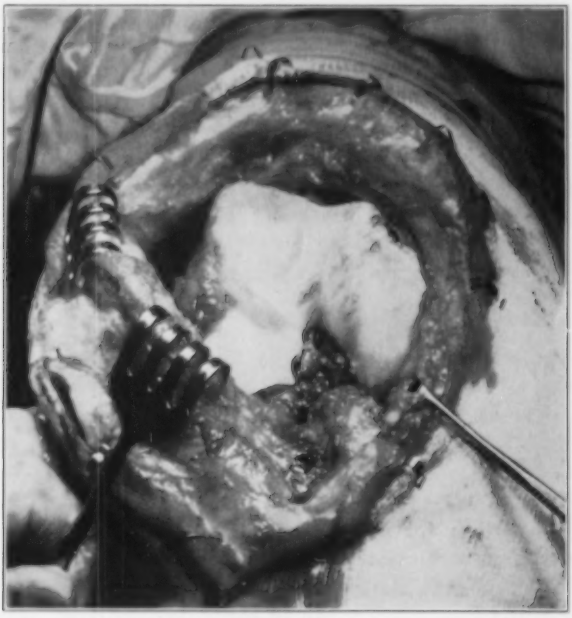

FIG. 6-B

Photograph of the knee during operation. Marginal erosion and bone invasion are shown.

cruciate ligamen· was involved and partially excised. A synovectomy and curetting of the bone lesions were done. Microscopic studies revealed pigmented villonodular synovitis.

The patient was last seen and examined January 28, 1960, at which time there was residual swelling of the knee and he was bearing weight with crutches. Radiation therapy had been contemplated, but the patient failed to return for follow-up study.

DISCUSSION

Simon, in 1865, is credited with first describing xanthoma of the synovial

membrane. Following his description, numerous terms have been used to describe these lesions, some of which are: xanthoma, xanthogranuloma, giant-cell tumor, myeloplaxoma, chronic hemorrhagic villous synovitis, giant-cell fibrohemangioma, fibrohemosideric sarcoma, sarcoma fusogiganto cellulare, benign polymorphocellular tumor of the synovial membrane, and malignant polymorphocellular tumor[8]. Jaffe, Lichtenstein, and Sutro, in 1941, reviewed the literature and found fifty-seven cases of this disease. They reported an additional twenty, and proposed the term *pigmented villonodular synovitis, bursitis, and tenosynovitis.* This descriptive term has been generally adopted, and is now in common use.

Etiology

The etiology of this disease is unknown. Jaffe, Lichtenstein, and Sutro concluded that the lesion is an inflammatory response to some unknown agent and that the disease is not a true tumor or neoplasm. Ghormley and Romness classified these lesions as primary xanthomatoses and called them xanthomata of the tendon sheaths and synovial membranes. They expressed the opinion that the lesion is not an inflammatory response to local hemorrhage or lipoid imbalance.

Trauma has been considered to be of some importance. The evidence for this is the serosanguineous to brownish joint fluid, the reddish brown or xanthochromic synovial membrane, and the presence of intracellular and extracellular hemosiderin in histological preparations from the synovial membrane. Young and Hudacek produced changes that simulated pigmented villonodular synovitis by injecting autogenous blood repeatedly into the knee joints and Achilles tendons of dogs. They concluded that repeated hemorrhages into a joint are necessary for the development of the lesion and that trauma could be the initiating factor. Soeur did similar studies by repeatedly injecting blood into knee joints of rabbits. He produced an intense reaction initially, but this regressed rapidly and the synovial membrane became apparently normal. The frequency of injuries and hemarthroses of joints, especially in the knees of young athletes, and yet the very small number of cases of pigmented villonodular synovitis reported, suggests that some other factor in addition to trauma is necessary to precipitate the disease.

Clinical Course and Findings

Pigmented villonodular synovitis has an insidious onset and is monarticular. Occasionally there is a history of injury. Both men and women are affected, and the most common age of incidence is young adult life, with a range from the third to the fifth decades. Swelling is usually noted first; this gradually increases over a period of months or years. Pain is rarely present early in the disease, although intermittent aching may be noted. Later, pain and a limp may develop.

The physical findings reveal diffuse enlargement of the joint, although a nodular localized mass or masses may be felt. There is no redness, but some increased heat is often present. Tenderness is not pronounced; increased free fluid, especially in the knee where it can be easily demonstrated, is present, and motion may be restricted by the swelling. Perforation through the joint capsule may occur with extension into surrounding areas, such as into the popliteal and calf regions with involvement of the knee and into the intrapelvic area in disease of the hip, as in the case reported by Carr, Berley, and Davis and in Case 4 reported here.

Aspiration of the joint will reveal, as a rule, a serosanguineous or yellowish brown fluid which usually recurs rapidly after aspiration.

Laboratory tests, including urinalysis, blood counts, sedimentation rate, and blood studies, reveal no abnormal findings.

Roentgenographic Findings

Roentgenograms of patients with pigmented villonodular synovitis, in whom invasion of bone has not occurred, usually reveal synovial thickening, which may be nodular, but no regional decalcification and no calcific deposits in the lesion. The cartilage space is usually preserved. Lewis described the roentgenographic findings with particular reference to the differentiation of this lesion from synovioma.

When invasion of the bones adjacent to the joint has occurred there may be one or more small or large discrete, cystlike lesions, some of which may have slightly sclerotic margins. No pronounced sclerosis occurs, and no overlying periosteal reaction has been observed.

Pathology

Jaffe, Lichtenstein, and Sutro described circumscribed and diffuse lesions. In the circumscribed form there are one or more yellow-brown outgrowths which are either sessile or tumor-like lesions on the end of a stalk. In the diffuse form the whole synovial membrane is brownish and covered with villous and coarse nodular outgrowths which may be predominantly nodular or villous.

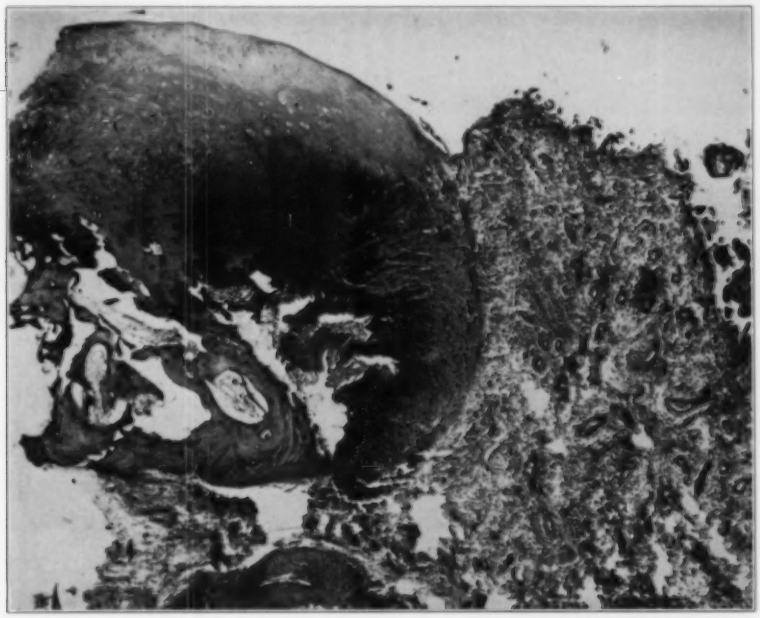

FIG. 7

Photomicrograph showing pigmented villonodular synovitis encroaching at the joint margin with bone invasion through a small opening.

The process may produce a gradual erosion of the articular cartilage starting at the articular margins as a pannus-like growth. This pannus formation may be of marked degree with tongue-like destructive extensions extending into the articular cartilage. Complete involvement of the articular cartilage has not been seen at operation, but marked narrowing of the cartilage space on the roentgenogram has been seen in far-advanced disease. Invasion and partial destruction of the cruciate ligaments also occurs.

Hemosiderin may be demonstrated in microscopic sections. It occurs intracellularly in the spindle and polyhedral stromal cells and also extracellularly.

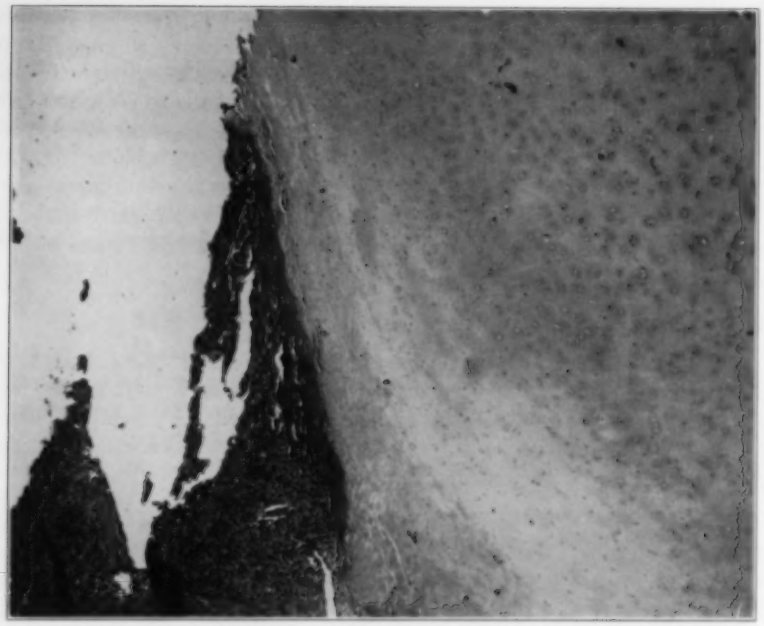

FIG. 8

Photomicrograph shows pannus extending over articular cartilage.

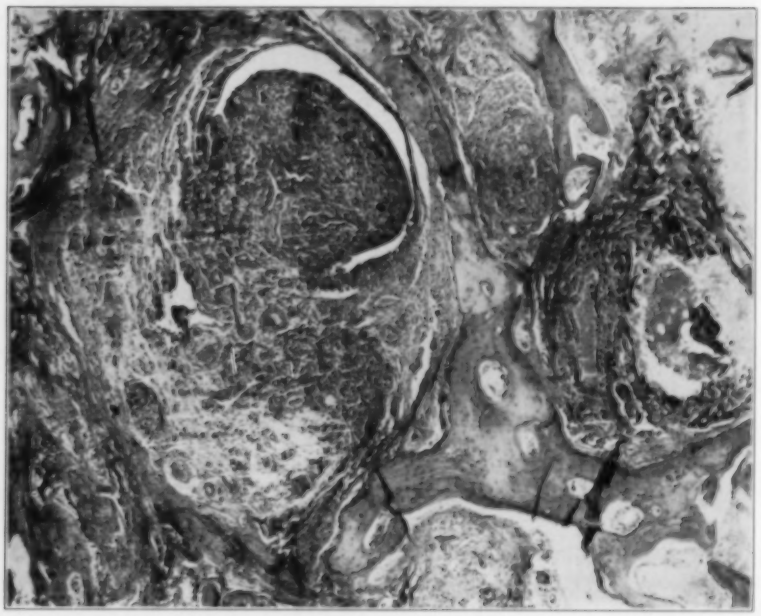

FIG. 9

Photomicrograph shows extensive invasion of bone.

Lipoid in varying amounts may be demonstrated with fat stains in the foam cells or even in the stromal cells. The lipoid occurs mainly in the form of cholesterol esters, and in large lesions containing necrotic areas and in lesions primarily subjected to trauma cholesterol crystals may be found. Numerous scattered giant

cells are a distinctive feature of these lesions, and usually numerous vascular channels can be seen as well.

The changes are ordinarily confined to the synovial membrane. When extension to the bones adjacent to the joint space does occur, the avenue of extension of the pigmented synovitis appears to be directly through articular cartilage and cortex at the chondro-osseous junction (Fig. 6-B). Extension occurs through a relatively small opening in the cartilage or cortical bone (Fig. 7). In the underlying softer cancellous bone the process expands slowly, producing an hour-glass-like lesion. On the roentgenogram the lesions in bone may be single or multiple and appear as small or large cystlike spaces quite well demarcated, at times with thin, sclerotic walls. These lesions are usually found in the opposing bones at the joint. Bone reaction with marked sclerosis surrounding the intra-osseous lesions is not common. The cartilage space may be narrowed in late stages as the result of the slow extension of the disease process onto the articular cartilage as a pannus which gradually erodes the cartilage (Fig. 8).

Microscopic studies of the bone lesions reveal the same histological features as the process present in the synovial membrane of the joint (Fig. 9).

Few cases have been reported in which invasion of bone has occurred. Two cases with bone involvement in the hip joint are recorded in the Case Records of the Massachusetts General Hospital (one in 1944, and one in 1951). Mallory [4], in discussing the latter case, stated: "In what way this lesion of the synovia produces cystic foci of destruction in the surrounding bone is not clear." Carr, Berley, and Davis, in 1954, reported a case with bone involvement of the hip; Ghormley and Romness, in 1954, reported four cases of pigmented villonodular synovitis of the hip, three of which had some cystic bone changes and a narrowed joint space; and Breimer and Freiberger, in 1958, reported three cases with invasion of bone, one in the hip and two in the elbow. Lewis, in commenting on the roentgenographic findings in this disease, stated that there are no cartilage changes and no bone abnormality, not even osteoporosis. He did, however, present two cases, one of the elbow, with invasion of the ulna, and one in the wrist, with invasion of the radius. He concluded that these instances are rare. Greenfield and Wallace said that the absence of osseous changes serves to differentiate the lesion from other diseases of bones and joints. However, they reported a case, with some erosion of the distal lateral portion of the tibia as seen on the roentgenogram; at operation the joint was found to be normal. This case may be similar to one reported by Breimer and Freiberger in which cystic defects were noted in the fibula and tibia but with only involvement of peroneal tendon sheaths demonstrated at operation. No mention was made of opening the ankle joint in this case and thus the disease may have been primarily in the tendon sheaths and not in the synovial membrane of the ankle. Minear, reporting on xanthomatous joint tumors, in 1951, described an ankle joint with a "pulsation type" of erosion of the tibia and the talus.

Thus, only twelve cases have been found in the literature with invasion of bone from an intra-articular lesion of pigmented villonodular synovitis, and no cases have been reported with invasion of bone in the knee joint. Levinthal and Kraft, when discussing the eradication of benign lytic bone tumors, reported a case of a xanthomatous bone cyst of the trochanteric area of the femur in a fifteen-year-old girl. This was curetted and cauterized, and bone grafts were inserted. X-ray therapy was given. Four years later, osteogenic sarcoma developed and the patient died. This case had some of the roentgenographic and pathological features of pigmented villonodular synovitis, but the later development of osteogenic sarcoma suggests that this was not a typical case of pigmented villonodular synovitis since there have been no known cases of either local malignant degeneration or metastases.

In contrast to the rarity of bone involvement with pigmented villonodular synovitis, Fletcher and Horn, Shafer and Larmon, Lewis, Breimer and Freiberger, and Lichtenstein described lesions in bone associated with villonodular tenosynovitis of tendon sheaths. Sherry and Anderson reported thirty-four cases of involvement of a tendon sheath and noted erosion of bone in the older lesions. The present report is not concerned with these rather familiar lesions, nor with villonodular bursitis, which was discussed by Jaffe and associates, as well as by Weisser and Robinson.

Treatment

Synovectomy is the treatment of choice for pigmented villonodular synovitis. If complete excision of the synovial membrane is not possible at operation then radiation therapy may be considered [8]. Local recurrences following synovectomy occur; they are best treated by excision and perhaps radiation therapy. Radiation therapy as primary treatment is inadequate in the author's opinion. Even for the treatment of recurrences, surgery is probably preferable.

When there are associated lesions in bone, synovectomy should be performed combined with careful curetting of the bone lesions. If sizable, these defects should be filled with bone chips or larger grafts. Postoperative roentgen therapy, when bone grafts have been used, is contra-indicated until an adequate blood supply to the graft area has been established and assimilation of the grafts is apparent on the roentgenogram, at not less than three or four months after surgery.

Prognosis

With adequate treatment of the primary lesion and of the recurrences, the prognosis for satisfactory function is good. If there is extensive involvement of bone and cartilage, degenerative changes and pain may necessitate arthrodesis, as in Case 1. After successful arthrodesis the lesion does not appear to progress.

SUMMARY

Six cases of pigmented villonodular synovitis with invasion of bone from intra-articular lesions are presented. Three of these were of the hip and three of the knee. Few such cases have been presented before in the literature, and no previous cases were found reported with invasion of bone at the knee joint.

NOTE: The author wishes to express his appreciation to Dr. Louis Lichtenstein for his collaboration in interpreting the pathology of the cases presented in this study.

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DISCUSSION

Dr. Henry L. Jaffe, New York, N. Y.: Dr. McMaster has given us an interesting and well documented account of the occurrence of bone involvement in cases of diffuse intra-articular pigmented villonodular synovitis. It is striking that of the six cases he presented in this connection, three involved the hip and three the knee joint. In regard to cases of diffuse pigmented villonodular synovitis, irrespective of bone involvement, one may estimate that for every case in which a hip joint is affected, there are at least ten to fifteen cases in which a knee joint is affected.

I would like to ask Dr. McMaster what the proportion of cases in the knee joint with bone involvement was among his total cases of pigmented villonodular synovitis of that joint. I surmise that the proportion is very small. It is also interesting in this connection that of the twelve cases collected by Dr. McMaster from the literature in which diffuse intra-articular pigmented villonodular synovitis was associated with bone involvement there were seven in which the lesion was in a hip joint and none in which it was in a knee joint. In my experience, too, bone involvement is rare in cases of diffuse pigmented villonodular synovitis of the knee joint, although I did illustrate such a case in my book. On the other hand, of the two cases I have seen of diffuse pigmented villonodular synovitis affecting a hip joint, both showed involvement of the bones entering into the joint. In any event, pigmented villonodular synovitis may present a complex problem in clinical diagnosis when the involved synovial tissue has penetrated one or another bone component of the joint and produced large areas of destruction.

I think that the reason involvement of bone is not common in the knee joint is that the knee joint offers the involved tissue ample room for growth and expansion. In the hip joint, on the other hand, the anatomical conditions are such as to favor erosion of the component bones by the involved tissue. This is also true in connection with tenosynovial (or fascial or ligamentous) villonodular lesions — especially those developing in toes, in other parts of the foot, or in the ankle. In these sites, in particular, the involved tissue is often so closely confined that, not infrequently, it erodes the regional bone or bones in the course of its growth and expansion.

A Device for Stress Inversion or Eversion Roentgenograms of the Ankle*

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The use of roentgenograms of the ankle, made while applying inversion or eversion stress to the foot, has been discussed frequently [1-13] as an important procedure in establishing an accurate diagnosis in acute or chronic ligamentous injuries of the ankle. Customarily, the stress has been applied manually — a method that has obvious disadvantages. The large number of ligamentous injuries of the ankle sustained by Army recruits at Fort Carson, Colorado, stimulated the development of a device for obtaining these roentgenograms which eliminates the need for manual application of the stress.

This article describes the fabrication and use of an apparatus which has proved entirely satisfactory and practical. It minimizes the surgeon's exposure to radiation, conserves his time, and eliminates motion of the foot during exposure of the roentgenograms, a frequent cause of poor roentgenograms with the manual technique. It is inexpensive, easy to apply, and compact enough to be transported with ease. In my experience, the apparatus has proved of definite value when stress roentgenograms were indicated.

THE DEVICE

The device consists of a foot piece, an anchoring thigh strap, and two connecting ropes which can be assembled quickly and inexpensively in any brace shop (Figs. 1 through 3). The materials needed include two 16-gauge sheets of aluminum for the foot plate; enough 24-ST aluminum or the equivalent for the turret clamps; two cold-rolled steel rods, three-eighths of an inch by six inches, for the connecting rods; welding rod, one-eighth of an inch in diameter, for the retaining rings; steel wire, three-sixteenths of an inch in diameter, for the rope clamps; one-inch webbing for the thigh strap; and approximately five feet of clothesline for the connecting rope. Fabrication of the apparatus includes shaping of the foot plates, drilling of the turret clamps and connecting rods, and bending of the retaining rings and rope clamps. The foot piece is padded with one-half inch thick felt over the surfaces that are in contact with the foot. A buckle and two ropes are attached to a piece of webbing, one-inch wide and eighteen inches in length, to make the anchoring strap (Fig. 2).

The device fits any adult foot and it can be adjusted to maintain inversion or eversion of the foot with the ankle in dorsiflexion, plantar flexion, or neutral position, chosen on the basis of clinical findings. It is easily applied as follows: The two parts of the foot piece are slid together along the connecting rods and adjusted so that they conform to the heel and fore part of the foot. An elastic bandage is wrapped firmly around the foot and the two parts of the foot piece, starting just above the ankle. The connecting rods are then slid through the turret clamps, either medially or laterally, depending on whether inversion or eversion stress is utilized. When the connecting rods are in proper position, the plates of the foot

* The opinions or assertions contained herein are those of the author and are not to be construed as official or reflecting the views of the Department of Defense, The Department of the Army, or the Office of the Surgeon General.

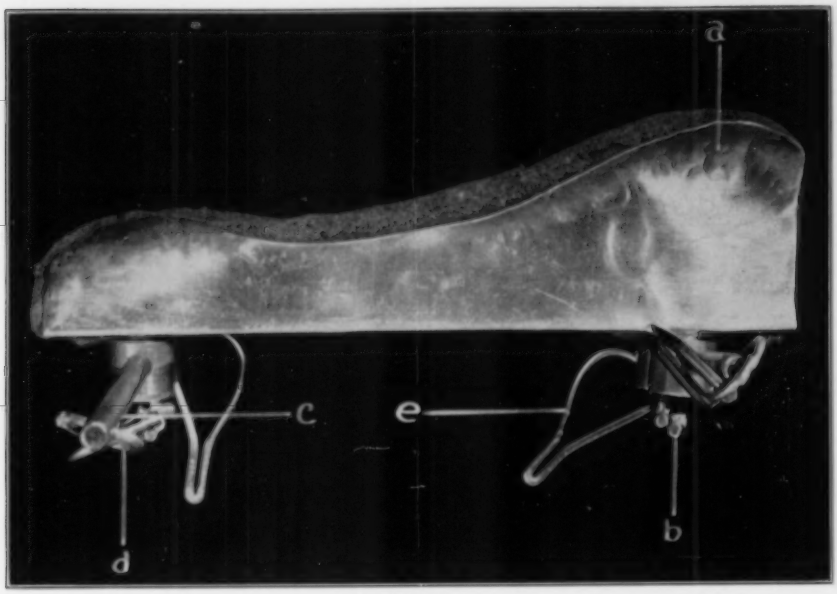

FIG. 1

Lateral view of the foot piece: a = heel flange; b = clamping screw; c = connecting rod; d = retaining ring; and e = rope clamp.

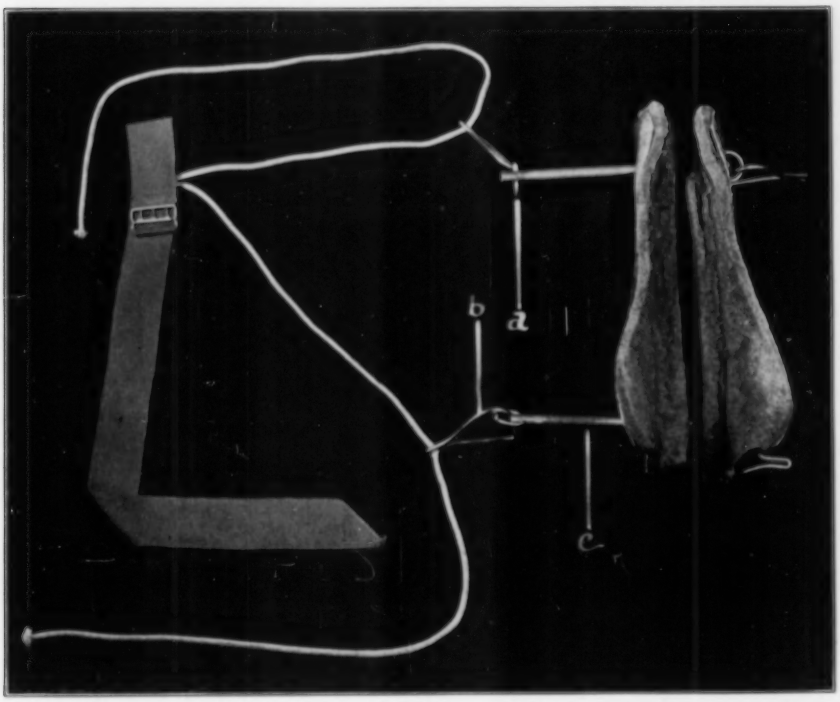

FIG. 2

Foot piece viewed from above, with anchor strap attached: a = retaining ring; b = rope clamp; and c = connecting rod.

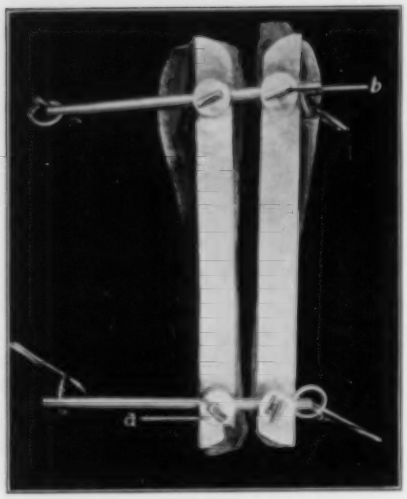

FIG. 3

FIG. 4

Fig. 3: Foot piece as viewed from below: a = turret clamp and b = clamping screw.
Fig. 4: Lower extremity with device applied for stress inversion roentgenogram.

piece are squeezed against the foot, and the screws of the turret clamps are tightened against the connecting rods. The anchoring strap is applied around the thigh just above the knee, with the two ropes on either the medial or lateral side, depending on whether inversion or eversion stress is to be applied. The adjustment of the length of the anterior cord allows stress to be applied with the foot in equinus position for the testing of the anterior talofibular ligament or in neutral position for the testing of the calcaneofibular ligament. To maintain the desired position of the ankle, the ropes are pulled through the tapered slots of the rope clamps until they are sufficiently taut. Properly applied, the device remains in position, and no motion of the foot can take place because the curves of the flanges and overlying felt hold the foot rigidly.

The amount of stress to be applied was determined in the normal ankle as the amount needed to just cause discomfort, and in the anesthetized, acutely injured ankle as the amount of stress needed to invert the ankle to the point where resistance to further inversion was felt. The amount of stress applied was not determined quantitatively, nor were precautions taken to assure that the same amount of stress was used in all ankles. All tests were performed by three individuals, and it is thought that reasonably comparable testing conditions were used throughout.

Both an anteroposterior and an oblique or mortise view were used when the roentgenograms were obtained. Comparison of the measurements of talar tilt obtained from anteroposterior and mortise roentgenograms in several instances revealed no difference in the angle determined. Since the device has a flat surface at the heel, perpendicular to the long axis of the foot, the foot is naturally held in the appropriate position for an anteroposterior projection when the patient is lying supine. For this reason, the anteroposterior projection was used for the most part.

The application of the device is a simple procedure that requires about one minute once proficiency in applying it has been achieved. If desired, the device can be used to apply stress in either external or internal rotation as the roentgenogram is made. This is accomplished by fixing the cross bars of the foot piece

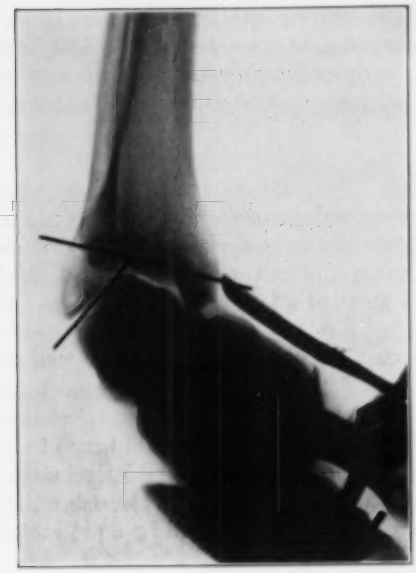

FIG. 5

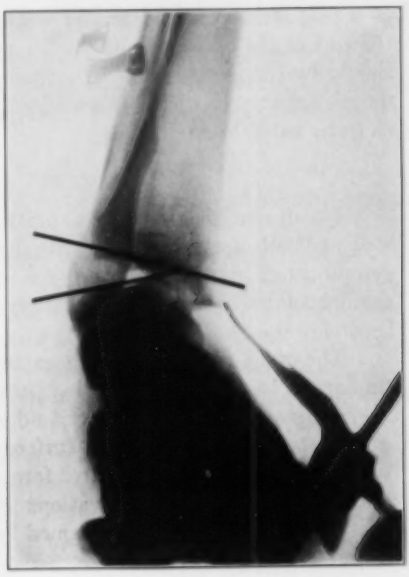

FIG. 6-A

Fig. 5: Stress inversion roentgenogram of a recruit, twenty-two years old, with an acute injury. Femoral-nerve and sciatic-nerve block was used. Exploration demonstrated disruption of all of the lateral ligaments of the ankle except for the posterior talofibular ligament.

Fig. 6-A: Stress inversion roentgenogram of a recruit, nineteen years old, with an acute injury. Femoral-nerve and sciatic-nerve block was used. Exploration demonstrated a tear of the anterior talofibular ligament and the lateral capsule and an incomplete tear of the calcaneofibular ligament.

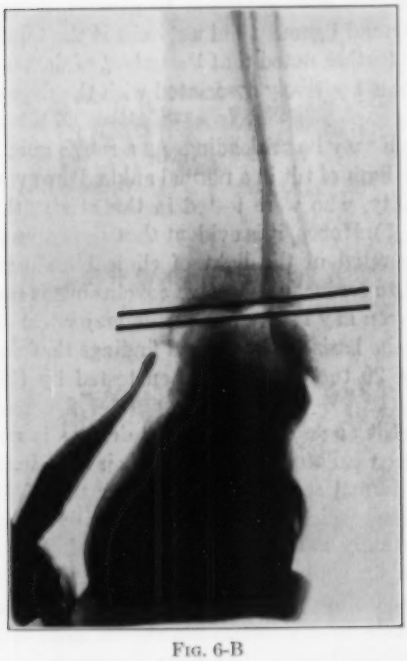

FIG. 6-B

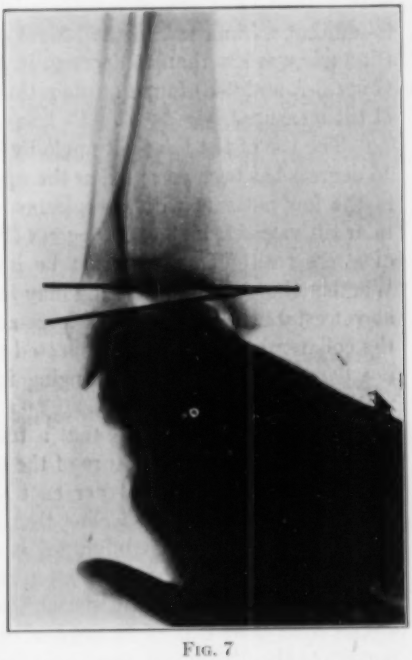

FIG. 7

Fig. 6-B: Stress inversion roentgenogram of the contralateral ankle. Anesthesia was not used.

Fig. 7: Stress inversion roentgenogram of a sergeant, thirty-eight years old, with a chronic dislocating ankle. Anesthesia was not used. The tilt of the contralateral ankle was nil.

to a ring stand with adjustable clamps and then by having the patient rotate the rest of the extremity internally or externally, as desired. With the foot held rigidly by the foot piece and ring stand, the desired rotational stress will be produced. Experience with this modification has been too limited for any conclusions as to its value to be drawn.

EXPERIENCE WITH THE DEVICE

The device has been used to make stress roentgenograms of both ankles of 125 patients with acute injuries to the ligaments of the ankle, of five patients with symptoms of chronic instability of the ankle, and of twenty-five patients with normal ankles, who were given a general anesthetic for surgical procedures not involving their ankles.

The talar-tilt angle was measured on the roentgenograms by a method similar to the one described by Rubin and Witten. Two lines were drawn on the roentgenograms: one corresponding to the tibial articular surface; the other corresponding to the articular surface of the talus. The subchondral bone of the two congruous articular surfaces forms dense lines with medial and lateral elevations. The apices of these elevations were used as reference points through which lines were drawn. The angle formed by these lines was measured by a protractor as the talar-tilt angle (Fig. 5).

A maximum tilt of 14 degrees was found in the unanesthetized normal ankles of patients with acute, contralateral injuries. In the normal ankles tested under general anesthesia, the maximum tilt was only 8 degrees. The maximum variation between the right and left ankles in the normal subjects was 10 degrees. In the anesthetized, injured ankles, talar tilt ranged from 0 to 70 degrees.

Forty of the 125 acute injuries were treated by surgical exploration. No ankles with a talar-tilt angle of less than 10 degrees were explored. In general, it was found that a frank tear of the lateral collateral ligament did not exist if the talar-tilt angle was less than 15 degrees. It was further noted that the extent of damage (Figs. 6-A and 6-B) found at operations was positively associated with the degree of tilt measured.

The use of the talar-tilt angle by itself may be misleading. As a rough guide, 15 degrees has been accepted as the upper limit of tilt in a normal ankle. However, in the few patients with chronic instability, who were tested in this study, the talar tilt varied from 8 to 15 degrees (Fig. 7). Hence, it is evident that the findings of stress roentgenograms must be interpreted in the light of clinical findings. Whether this method of testing may lead to erroneous negative conclusions is not as yet established. However, I have not seen any ankles in which a major tear of the collateral ligament was suspected on the basis of the clinical findings that did not demonstrate talar tilts ranging from 20 to 70 degrees when tested by this method.

Rubin and Witten feel that a talar-tilt angle of less than 23 degrees is not a reliable indication of rupture of the fibular collateral ligament. Their data indicate that approximately 4 per cent of normal ankles manifest talar tilt of 15 degrees or more. It is my feeling that a tool, which can be employed with 96 per cent accuracy, while not infallible, is certainly valuable as a clinical aid. Moreover, if the talar-tilt angle is interpreted in conjunction with clinical findings, diagnostic error will be further minimized. In my experience, acutely injured ankles with talar tilts of 15 degrees or more have at operation shown tears of a portion of the fibular collateral ligament. Preliminarily, it appears that the injured ankle, which exhibits talar tilt ranging from 10 to 15 degrees, presents the greatest source of possible diagnostic error.

The indications for stress testing with this device are:

1. Special features in the patient's history, such as the quick onset of severe disability at the time of injury, rapid onset of edema and ecchymosis after injury, and an injury, which on careful questioning is found to have involved moderate to major stress;

2. Physical findings of ecchymosis, severe edema, marked tenderness localized to the region of the collateral ligaments, clinical instability, and marked pain on weight-bearing;

3. Failure of routine anteroposterior, lateral, and oblique views to demonstrate pathological changes that are consistent with the history of physical findings.

Stress testing in an acute injury of the ankle is an uncomfortable procedure at best, even when performed very gently and slowly, either manually or with the device. In view of this and in order to eliminate muscle spasm, I have employed femoral-nerve and sciatic-nerve block or peroneal-nerve and tibial-nerve block, routinely, in the testing of acute injuries.

No complications have arisen that I can attribute to the device. At operations for the repair of acutely ruptured ligaments, I have attempted to extend incomplete tears of the lateral collateral ligament by application of a marked inversion stress on the ankle, but have been unable to do so. In view of this experience, it does not seem likely that stress testing will increase the damage that has already occurred.

Complete tears of the deltoid ligament have usually been associated with roentgenographic evidence of talar displacement in routine views of the ankle so I have had little occasion to use stress roentgenography in demonstrating injuries of this type. My experience with a program of primary suture of torn collateral ligaments of the ankle will be the subject of a future report.

SUMMARY

1. A practical and effective device is described for the maintaining of stress on the ankle in inversion or eversion while roentgenograms are made. The apparatus can be constructed at minimum cost and is simple to apply. At the same time, it is small and compact, making it easy to store and transport with a portable x-ray machine.

2. By the providing of rigid fixation the device eliminates movement and thus makes it possible to obtain better roentgenograms. Also, the device enables reduction of the x-ray exposure to the surgeon or technician who would otherwise have to hold the ankle.

3. The device has been used on a large number of army personnel with both normal ankles and ankles in which there were acute injuries of the ligaments and ankles with chronic instability. Accurate diagnosis of injuries of the collateral ligaments of the ankle has been made possible by use of this device.

4. No evidence has been found that stress testing increases the extent of acute ligamentous injuries. Attempts to increase the tears found at the time of operation on the ankles with acute injuries to the lateral collateral ligaments were uniformly unsuccessful, even though forceful inversion of the foot was carried out.

5. The findings in stress roentgenograms must be interpreted in the light of the clinical findings.

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DISCUSSION

Dr. Carruth John Wagner, Washington, D. C.: Fractures of the greater multangular are rare, and isolated fractures even more rare. This, of course, is because the usual injury is of an indirect rather than of a direct nature. In the usual case, there is a fracture-dislocation of the first carpometacarpal joint. The multangular fracture is usually accompanied by a Bennett type of fracture of the first metacarpal or avulsion of the radial aspect of the second metacarpal base, or both. Isolated fractures, as indicated in the authors' series, are almost invariably due to direct blows to the wrist.

As in two of the authors' cases, diagnosis is not always easy. The usual roentgenogram of the wrist reveal the greater multangular to be overlapped partially by the lesser multangular, navicular, and the first and second metacarpals. I have found it helpful in studying roentgenograms of

(Continued on page 1260)

Narrowing of the Intervertebral-Disc Space in Children

Presumably an Infectious Lesion of the Disc

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From the Children's Hospital of the East Bay, Oakland

The purpose of this study is to describe and call attention to a lesion of the intervertebral disc in children. The presenting symptoms, as well as the physical, laboratory, and roentgenographic findings, suggest that this is probably an infectious process. The lesion resembles osteomyelitis of the spine in many ways, but because of the minimum and infrequent involvement of the vertebrae, it is believed that the condition should be regarded as a separate entity. The findings in a study of sixteen children with this disorder are presented.

REVIEW OF THE LITERATURE

In 1933, under the title "A Benign Form of Osteomyelitis of the Spine", Smith described his observations in seventeen patients from five to fifty-eight years of age, with an average age of 31.5 years. The chief symptoms were mild backache and low-grade fever. In two patients roentgenograms of the spine demonstrated only narrowing of the intervertebral space; in five others, there was narrowing of the interspace combined with partial vertebral destruction. Harbin and Epton noted that in many patients with osteomyelitis of the spine, the infection involved the intervertebral disc, without osseous involvement. In 1940, Ghormley, Bickel, and Dickson described a disorder in adults which they termed "acute infectious lesions of the intervertebral disks". They observed that the clinical signs of infection were pain, spasm, and tenderness over the involved areas of the spine. Roentgenographic examination during the acute stage revealed no striking changes, but subsequent studies demonstrated progressive narrowing of the intervertebral space. This narrowing was followed by bone proliferation along the margins of the affected vertebrae. These authors reasoned that if vertebral involvement was extensive, a diagnosis of osteomyelitis should be made; if only minimum changes were present, they assumed that the lesion did not represent osteomyelitis, but rather an infection of the disc. Bremner and Neligan observed seven children (nine months to two and one-half years of age) with "acute osteitis of the spine". The course of the illness was benign, but narrowing of the intervertebral-disc space was demonstrated. Tuberculin skin tests were negative and recovery was complete. In describing his observations in four children (two to fourteen years of age) Saenger used the term "spondylarthritis" to identify a clinical condition characterized roentgenographically by narrowing of the intervertebral space and mild destruction of the adjacent surfaces of the vertebrae. He emphasized the importance of differentiating this condition from tuberculous spondylitis. Saenger could not demonstrate a specific causative agent, but considered trauma and infection significant in the pathogenesis. Mathews, Wiltse, and Karbelnig, in 1957, proposed that the disorder was a primary disease of the intervertebral disc. From their study of nine children, they concluded that the condition is self-limited and the prognosis good.

CLINICAL PICTURE

A study has been made of the clinical records of sixteen children, in which there had been a diagnosis of a lesion of the intervertebral disc. Between 1952 and 1960, nine of these patients were admitted to the Children's Hospital of the East Bay, Oakland, California, and four and three patients, respectively, were admitted to Stanford Hospital and the University of California H. C. Moffitt Hospital in San Francisco. The typical patient in this group was a child between two and four years of age, who, for seven to ten days before admission had symptoms which included fever; stiffness of the back; back or hip pain; limp; refusal to sit, stand, or

Figs. 1-A through 1-G: Case 9, a boy, three years and five months old. Note the progressive narrowing of the interspace between the fourth and fifth lumbar vertebrae and the sclerosis of the adjacent vertebral plates.

FIG. 1-A
December 8, 1952.

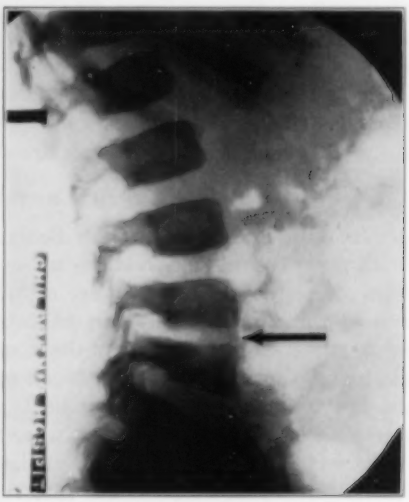

FIG. 1-B
December 8, 1952.

FIG. 1-C
December 30, 1952.

FIG. 1-D
January 21, 1953.

FIG. 1-E
June 10, 1955.

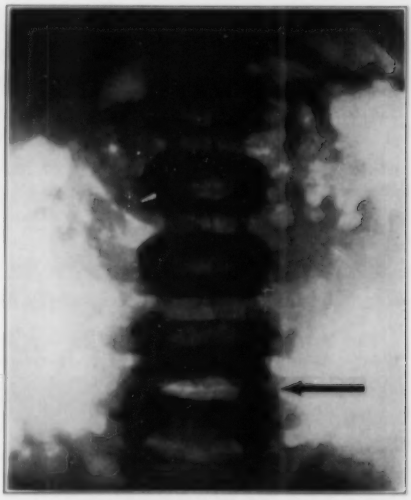

FIG. 1-F
January 7, 1957.

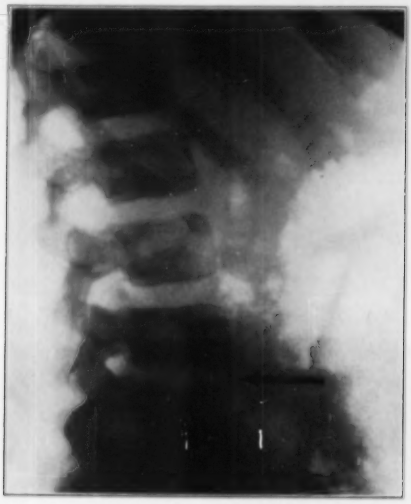

FIG. 1-G
January 7, 1957.

walk; and unexplained night crying. Trauma to the back or hips, an infection of the respiratory tract, or an episode of diarrhea may have occurred in conjunction with the onset of the illness. The temperature in some instances is as high as 101 degrees Fahrenheit. Although the child does not appear to be acutely ill, he is very irritable and prefers the recumbent position. There is severe spasm of the muscles of the lower part of the back, with accentuation of the lumbar lordosis. There is a slightly elevated leukocyte count and an increase in polymorphonuclears. Urinalysis is within normal limits, and the tuberculin skin test is negative. The sedimentation rate is moderately elevated at first but returns to normal in four to six weeks. Within one to two weeks, the temperature returns to normal, but three to four weeks are required before the child is completely asymptomatic. Roentgenograms

of the spine at the onset of symptoms may be negative, but one to two weeks later narrowing of a lumbar intervertebral space may be observed.

During the next two to eight months there is gradual widening of the intervertebral space, and in very young children the involved interspace may be restored virtually to normal within one year. The typical roentgenographic changes are presented in the accompanying illustrations.

Observations concerning the study of sixteen children are summarized in Table I.

DISCUSSION

The nature of the blood supply to the intervertebral disc may be of signifi-

Figs. 2-A through 2-G: Case 3, a girl, eighteen months old. Note the progressive narrowing and the nearly complete restoration of the interspace between the fourth and fifth lumbar vertebrae.

FIG. 2-A
November 20, 1952.

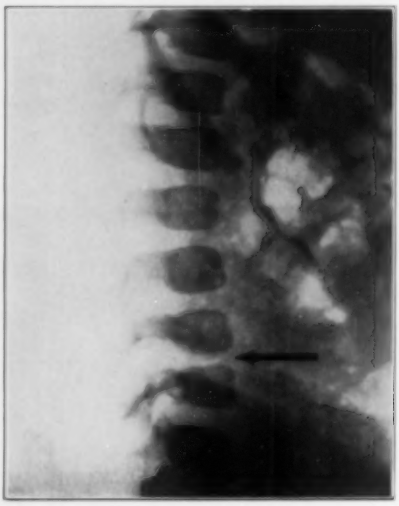

FIG. 2-B
November 20, 1952.

FIG. 2-C
December 24, 1952.

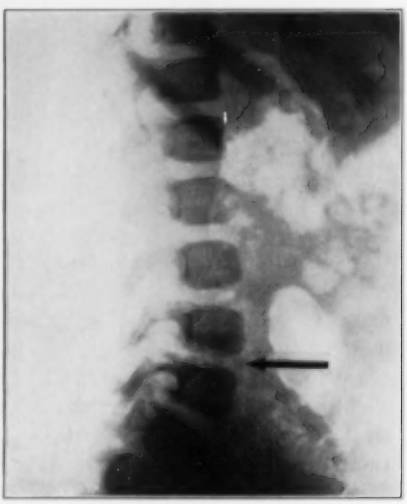

FIG. 2-D
April 16, 1953.

cance in explaining the mechanisms involved in the disorder under consideration. If an infectious cause is assumed, the blood supply to the disc, which is present in childhood, would make it possible for bacteria to gain entrance into the disc in a way which is not possible in the adult. Böhmig noted that the intervertebral disc in the embryo, as well as that in the young child, receives a blood supply from the surfaces of the adjacent vertebral bodies. On the basis of his studies, he stated that infectious blood diseases could affect the disc up to the twentieth year of age. The studies of Uebermuth, Smith [15], and Coventry, Ghormley, and Kernohan also support the existence of vascular channels to the intervertebral disc in the early years of life. The observation that thirteen of the patients in the present study were five years of age, or less, is significant in view of the greater blood supply to the intervertebral disc in early life. The observation that the disc

FIG. 2-E
October 14, 1953.

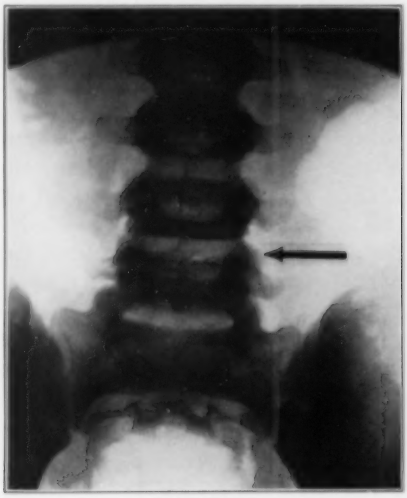

FIG. 2-F
October 7, 1957.

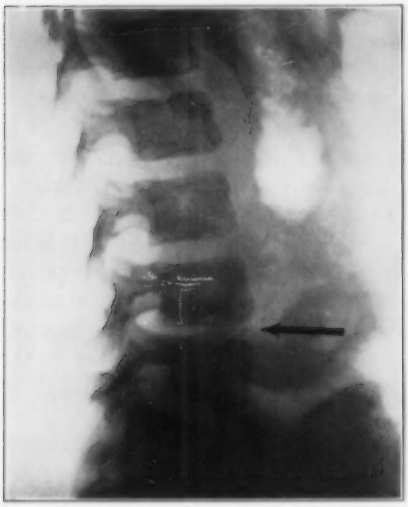

FIG. 2-G
October 7, 1957.

FIG. 3-A
Case 1, January 20, 1959.

space is sometimes completely restored in very young children, in contrast with the incomplete restoration in older children and adults, may reflect the decreasing blood supply to the disc that accompanies increasing age. However, this restoration may also be due to the greater residual growth and development of the disc in the younger child.

The fact that seven of the sixteen children had a history of trauma to the back or hips may be significant. Wilensky stated that trauma may help to localize an infection by injury to the blood vessels, so that a thrombus could form or an infected embolus could lodge in a vertebra. Kulowski noted a history of trauma in 30 per cent of 102 patients with osteomyelitis of the spine. Atsatt reported osteomyelitis occurring after a closed compression fracture of a vertebra.

The observation that an infection of some type is occasionally associated with the onset of this illness merits attention. Mathews, Wiltse, and Karbelnig studied the anti-streptolysin titer in one of their nine patients. The titer, determined three and four weeks after the onset of illness, was extremely high, as compared with the titer taken eight months later. In reviewing the history of their patient, they found that no preceding streptococcal infection had been noted, although the onset of the illness resembled an infection of the respiratory tract. Many years earlier, Mayer reported a five-year-old girl with a streptococcal infection of the spine in whom kyphosis developed, without evidence of bone destruction. In his patient, *Streptococcus viridans* was cultured from the blood, and narrowing of the intervertebral space was noted on the roentgenogram. This case presumably represented an intervertebral-disc lesion of the type under consideration here. Hurwitz and Albertson, as well as Adlerman and Duff, reported osteomyelitis of the spine as a complication of urinary-tract disease. They observed that the spread of infection was probably by the venous pathway from the prostatic and periprostatic veins to the vertebral veins. Batson described the role of the vertebral veins in the spread of metastases from the genito-urinary tract. In view of the blood supply to the intervertebral disc in children, it seems reasonable to postulate that trauma to the back in the presence of a transient bacteremia from various causes could localize an infection in the intervertebral disc. It is apparent from these studies that laboratory studies, including blood and stool cultures, and agglutination procedures have been ineffective in demonstrating the etiology of this lesion (Table I). A promising method for gaining further knowledge of the condition would be the study of material taken from the involved intervertebral space at the time of acute symptoms. Three patients in this series had either needle aspiration or surgical biopsy of the affected vertebral interspace. In Case 15, needle biopsy of the involved interspace under roentgenographic control failed to yield infectious material. Needle aspiration in Case 13 yielded three milliliters of seropurulent material which, when cultured, failed to demonstrate bacterial or fungal growth. The pathological report, however, stated that the specimen submitted demonstrated "inflammation, acute of the intervertebral disc". Open biopsy of the disc lesion in Case 16 led to a diagnosis of chronic osteomyelitis. It should be noted that this diagnosis was based on the microscopic appearance of disc material and bone removed from the adjacent vertebral plate under direct vision in the operating room.

It would appear that the clinical and roentgenographic findings in these sixteen patients are not typical of the usual form of vertebral osteomyelitis. In this regard it may be noted that the duration of symptoms and the morbidity were much less, and the physical findings were less pronounced, than would be expected with the usual case of vertebral osteomyelitis. In addition, although

narrowing of the intervertebral-disc space was obvious roentgenographically in every instance, minimum vertebral involvement was noted in only three patients, Cases 7, 11, and 12. The paucity of vertebral involvement in these three patients and the absence of such involvement in the remainder of the patients are not consistent with a diagnosis of osteomyelitis of the spine. The distinction between osteomyelitis and the disorder under consideration may be difficult to make. It is believed, however, that this lesion probably represents an infectious process completely or almost completely limited to the intervertebral disc.

Figs. 3-A through 3-E: Case 1, a girl, twenty-one months old. Note the early narrowing and the eventual restoration of the interspace between the third and fourth lumbar vertebrae.

FIG. 3-B
January 20, 1959.

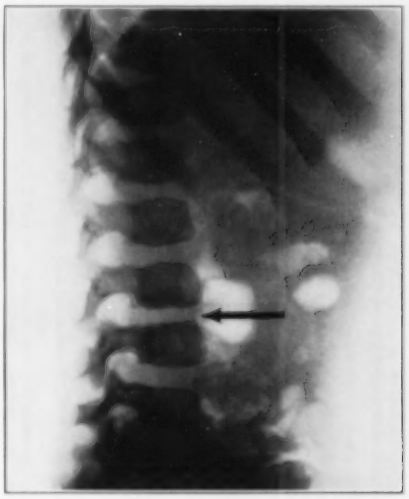

FIG. 3-C
May 4, 1959.

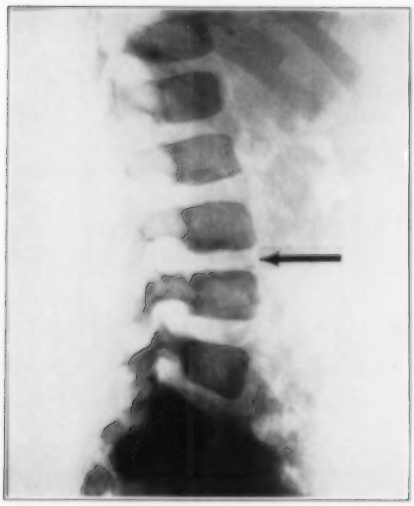

FIG. 3-D
December 14, 1959.

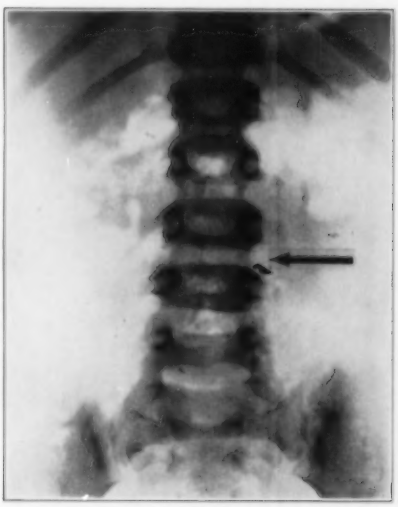

FIG. 3-E
December 14, 1959.

TABLE 1

Case No.	Age at Onset	Sex	History and Presenting Symptoms	Physical Findings	Temperature (*Degrees Fahrenheit*)	Sedimentation Rate (Wintrobe) *Mm/Hr*	White Blood Count	Tuberculin Skin Test Purified Protein Derivative Test Strength	Tuberculin Skin Test Purified Protein Derivative Result	Roentgenographic Findings	Bacteriological Studies	Treatment and Duration	Antibiotic Therapy Drug	Antibiotic Therapy Dose	Antibiotic Therapy Duration	Antibiotic Therapy Hospital Day Initiated	Condition When Last Seen Clinical	Condition When Last Seen Roentgenographic	Follow-up Period
1	21 mos.	F	Playmate stepped on patient's back; 5-day history of refusal to sit or stand; back pain and diarrhea	Back muscle spasm; nuchal rigidity	99.6	14	12,400	1st 2nd	Neg. Neg.	Narrowing, L3–L4 interspace	Stool culture negative for pathogens	Bedrest, 3 wks.; cast, 3 mos.	Penicillin	400,000 units, b.i.d.	10 days	2nd	Complete recovery	Restoration of disc space	1.5 yrs.
2	1 yr.	F	8-day history of fever, anorexia, lumbar lordosis; would not sit or stand; diarrhea; back and neck weakness	Back muscle spasm; nuchal rigidity	100	15	17,500	2nd 2nd	Neg. Neg.	Narrowing, L2–L3 interspace	Stool culture negative; agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 6 wks.	None				Well to date	To date: incomplete restoration of interspace	9 mos.
3	18 mos.	F	10-day history of fever, leg pain; refused to walk	Back muscle spasm	101	15	9,600	2nd 2nd	Neg. Neg.	Narrowing, L4–L5 interspace	Agglutinations negative; anti-streptolysin titer less than 12 Todd units	Bedrest 2 wks.	Penicillin	400,000 units, b.i.d.	10 days	4th	Complete recovery	Partial restoration of disc space	6 yrs.
4	4 yrs.	F	6-day history of fever; left hip pain; lumbar lordosis	Back muscle spasm	99.6	33	11,200	1st 2nd	Neg. Neg.	Narrowing, L2–L3 interspace	Blood and stool culture negative	Bedrest, 5 wks.; cast, 2 mos.	None				Well to date	To date: incomplete restoration of disc space	3 mos.
5	5 yrs.	F	Respiratory-tract infection followed by back pain and night crying of 10 days' duration	Resistance to back motion; nuchal rigidity	100	15	7,000	1st 2nd	Neg. Neg.	Narrowing, L1–L2 interspace	Agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 3 wks.; cast, 3 mos.	Penicillin	400,000 units, b.i.d.	8 days	11th	Complete recovery	Persistent narrowing of interspace	5 yrs.
6	16 mos.	M	7-day history of limp, lordosis, and apparent leg weakness following fall	Back muscle spasm	100	2	15,200	1st 2nd	Neg. Neg.	Narrowing, L4–L5 interspace	None	Bedrest, 4 wks.	None				Complete recovery	Nearly complete restoration of interspace	3 yrs.
7	2 yrs.	M	9-day history of refusal to sit or stand; night crying; back and neck stiffness	Back muscle spasm	101	33	10,300	1st 2nd 2nd	Neg. Neg. Neg.	Narrowing, L3–L4 interspace; slight demineralization, adjacent vertebrae	Blood culture negative; anti-streptolysin titer less than 12 Todd units	Bedrest, 6 wks.; cast, 2 mos.	Tetracycline	250 mg., q.i.d.	5 wks.	30th	Complete recovery	Nearly complete restoration of interspace	7 yrs.
													Sulfadiazine	200 mg., q.i.d.	5 wks.	30th			
8	6 yrs.	M	14-day history of difficulty in walking and hip pain following a fall	Back muscle spasm	101	32	11,000	1st 2nd	Neg. Neg.	Narrowing, L3–L4 interspace	None	Bedrest, 5 wks.; cast, 4 mos.	Penicillin*	400,000 units, b.i.d.	24 days	1st	Complete recovery	Persistent narrowing of interspace	8 yrs.

9	3.5 yrs.	M	3-day history of inability to sit or walk following a fall striking back	Back muscle spasm	100	37	10,350	1st 1st 2nd	Neg. Neg. Neg.	Narrowing, L4–L5 interspace	None	Bedrest, 2 mos.; cast, 4 mos.	Penicillin	400,000 units, b.i.d.	14 days	5th	Complete recovery	Partial restoration of disc space	7 yrs.
10	4 yrs.	F	10-day history of right hip pain, limp, and lumbar lordosis after falling out of bed	Back muscle spasm	100	38	13,600	1st 2nd	Neg. Neg.	Narrowing, L3–L4 interspace	None	Bedrest, 1 mo.; cast, 3 mos.	Penicillin	600,000 units, b.i.d.	14 days	4th	Complete recovery	Persistent narrowing of interspace	3 yrs.
11	21 mos.	M	2-week history of inability to sit or stand; extremely irritable	Limp, tenderness over lumbar spine	100	50	9,200	1st 2nd	Neg. Neg.	Narrowing, L3–L4 interspace; minimum destruction of adjacent vertebral surfaces	Agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 3 wks.; cast, 3 mos.	None				Well to date	No change from initial roentgenograms	3 mos.
12	9 yrs.	M	2-day history of fever, back pain, irritability, and lumbar lordosis following fall from bicycle	Tenderness over lumbar spine	101	34	12,000	1st 2nd 2nd	Neg. Neg. Neg.	Narrowing, L4–L5 interspace; minimum sclerosis of adjacent vertebral surfaces	None	Spine fusion L3 to S1 (clinical diagnosis of tuberculosis)	None				Asymptomatic	Fusion (surgical); presistent narrowing of interspace	8 yrs.
13	7 yrs.	F	3-day history of right hip pain; inability to walk following influenza and fall from a swing	Right thigh flexed with muscle spasm	101	50	12,200	1st 2nd	Neg. Neg.	Narrowing, L4–L5 interspace	Agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 3 wks.; brace, 4 mos.	Penicillin	600,000 units, b.i.d.	3 wks.	2nd	Complete recovery	Persistent narrowing of interspace	2 yrs.
14	22 mos.	F	4-day history of inability to walk and irritability	Lumbar lordosis	100	42	13,200	1st 2nd	Neg. Neg.	Narrowing, L4–L5 interspace	Agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 4 wks.; cast, 3 mos.	Penicillin	400,000 units, b.i.d.	3 wks.	3rd	Complete recovery	Complete restoration of disc space	2 yrs.
15	4 yrs.	M	2-week history of left hip pain and waddling gait following dog bite on cheek	Lordotic gait; guarding left hip	101	54	7,900	2nd 2nd	Neg. Neg.	Narrowing, L4–L5 interspace	Agglutinations negative (typhoid, paratyphoid, brucella)	Bedrest, 2 wks.; cast, 3 mos.	Penicillin	600,000 units, b.i.d.	2 wks.	2nd	Complete recovery	Partial restoration of disc space	2.5 yrs.
16	9 mos.	F	5-day history of back pain, limp, and night crying following respiratory-tract infection	Back muscle spasm	100	35	10,500	1st 2nd	Neg. Neg.	Narrowing, L5–S1 interspace	Agglutinations negative (typhoid, paratyphoid, brucella); blood culture negative	Bedrest, 3 wks.	Penicillin	600,000 units, b.i.d.	3 wks.	3rd	Complete recovery	Complete restoration of disc space	5 yrs.

* 400 milligrams streptomycin, t.i.d., initiated on twenty-fifth day and maintained for seven days.

TREATMENT

All patients were treated by bedrest during the acute phase of their illness. The average duration of bedrest was one month. After acute symptoms had subsided, eleven patients were placed in some form of back support, either a plaster body jacket or brace. From the information available in the records, it is difficult to determine the value of this aspect of therapy. As far as can be determined, there were no striking differences between the results in the patients treated with back supports and the results in those treated without back supports. However, it would seem reasonable to assume that some form of back support would be indicated for a period of three to four months. As a part of their therapy, eleven patients received antibiotics in some form (Table I). Although no recommendations can be made from this small series of cases concerning the use of antibiotics, it would appear that antibiotic therapy is indicated if an infectious etiology is assumed.

SUMMARY AND CONCLUSIONS

Attention has been called to a destructive lesion of the spine in children which involves the intervertebral disc. The disorder is similar to osteomyelitis of the spine, but because of the infrequent and minimum vertebral involvement, it is believed that the condition should be regarded as a separate entity. A series of sixteen patients is presented and the clinical picture and roentgenographic findings are described. The etiology, although not definitely established, is very likely infectious. Trauma to the spine in the presence of transient bacteremia may play a role in the pathogenesis.

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Failure by Corrosion of a Steinmann Pin Used for Intramedullary Fixation*

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When a surgeon uses a metallic device for internal fixation of a fracture and the device either breaks or excites excessive tissue reaction, it is often difficult to decide whether the metallurgical features of the device are to blame. Thorough studies of individual cases are infrequent[1,2,4] and few clinicians are familiar with the principles of metallurgical investigation of devices that have failed. In most

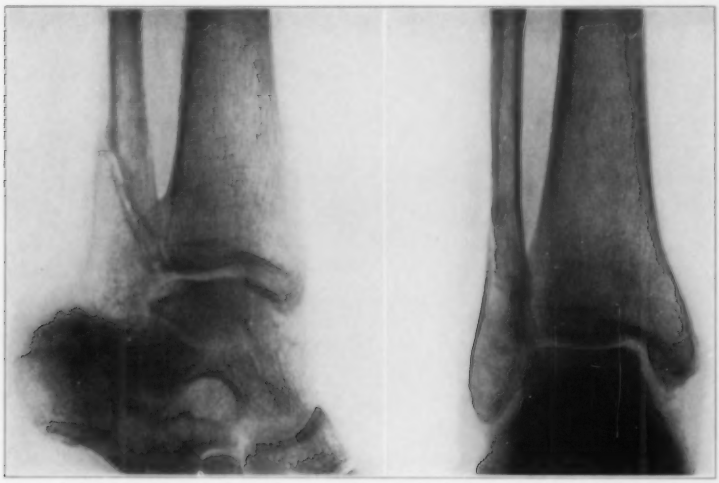

FIG. 1

Anteroposterior and oblique views of the right ankle of a woman, fifty-two years old. The roentgenograms, made approximately one year after injury, show non-union of an oblique fracture of the distal end of the fibula and slight widening of the ankle mortise.

published reports the causes for metallic failure have not been investigated and frequently the actual or apparent sequence of events which led to failure is not given in adequate detail. Often the appropriate tests, now part of modern metallurgical practice, were not even applied to the device.

The present case report concerns a failure of a Steinmann pin which was used as an intramedullary rod for fixation of a fracture of the fibula. Some of the facts uncovered during the investigation of this case are of general interest and have wide application in problems of internal implantation of metallic appliances.

A woman, fifty-two years old, was seen for non-union of a fracture of the lateral malleolus of the right fibula (Fig. 1). One year previously the patient had a trimalleolar fracture treated by closed reduction and plaster-cast immobilization. On September 18, 1956, the fibular fragments were cleared of intervening fibrocartilaginous tissue and the talotibial subluxation was reduced. A

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large lag screw of 18-8 SMO stainless steel inserted obliquely through the fibula into the tibia was used to narrow the widened ankle mortise and a stainless-steel Steinmann pin was drilled proximally through the lateral malleolus into the fibular medullary cavity to maintain alignment of the fracture fragments. An iliac-bone graft was applied across the fracture gap (Fig. 2-A).

About two months later the patient began to complain of pain over the lateral aspect of the fibula. Two weeks after the pain began, roentgenograms revealed signs of healing of the fracture (Fig. 2-B), but on the medial side of the fibula at the junction of its middle and distal one-thirds, there was some rarefaction and associated subperiosteal new-bone formation. This new bone did not extend to the area of fracture. Since the patient had had a questionably malignant lesion excised from the breast two years before, this area raised a considerable problem in differential diagnosis. Therefore, the area of periosteal reaction was biopsied at the same time the screw and pin were removed. The pin was withdrawn through the distal end of the fibula. The tissue removed from the region of the subperiosteal reaction in the fibula consisted of viable and necrotic granulation tissue, containing many foreign-body giant cells filled with brown pigment and large numbers of lymphocytes, plasma cells, and occasional polymorphonuclear leukocytes. An iron stain revealed large amounts of blue material in the macrophages and in the areas of brown pigmentation. The histological diagnosis was rust granuloma (Fig. 3).

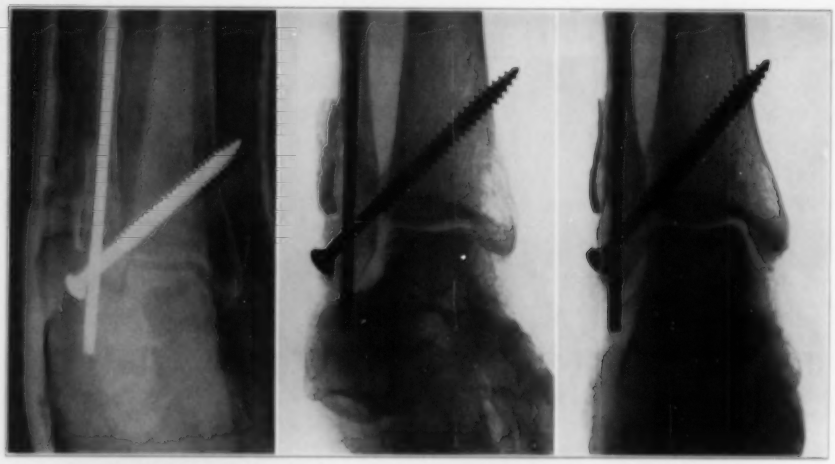

FIG. 2-A FIG. 2-B

Fig. 2-A: Roentgenogram made after operation shows maintenance of the normal width of the mortise by a transfixion screw and the fibular fragments fixed in proper alignment by an intramedullary Steinmann pin. Note bowing of the pin toward the tibia.

Fig. 2-B: Anteroposterior and oblique roentgenograms made ten weeks after surgery show the onlay bone graft, healing of non-union, and maintenance of the normal width of the ankle mortise. Note the punched-out destructive lesion of the fibula and subperiosteal reaction at the apex of the bow of the pin.

The screw revealed no defects on careful gross examination. The Steinmann pin showed several defects. The bend visible on the postoperative roentgenogram (Fig. 2-A) was maintained. Areas of tarnish were evident all along the shaft and tip of the pin. At the middle of the shaft, extending nearly to the pointed tip, there was a series of pits in the metal. These were oriented longitudinally (Figs. 4-A, 4-B, and 4-C) and measured from less than one millimeter to one centimeter in length and about one-half millimeter in width. They were filled with black granules of a crumbly material which, when removed, was shown by chemical analysis to be principally iron salts. The depth of the pits varied up to three millimeters, as determined by probing. The pits were most conspicuous on the convex side of the pin, but a smaller number of small pits was also evident on the concave side and scattered over the rest of the surface.

The first steps in the study of the pin were attempts to determine its origin. The pin had been originally obtained by the hospital through Army surplus channels. Correspondence with the manufacturing company, which was identified by stamp marks, revealed that Steinmann pins made by that company ". . . were made only for the Army during World War II; also we learned that quite a few

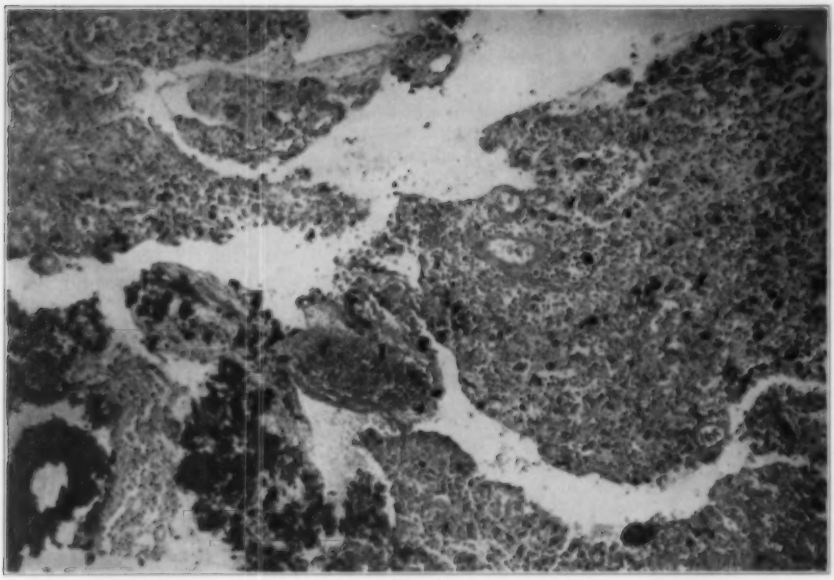

FIG. 3

Tissue from marrow cavity of the fibula adjacent to the area of bone rarefaction, stained with Prussian blue, revealed deposits of iron salts in phagocytes and in black amorphous and crystalline foci.

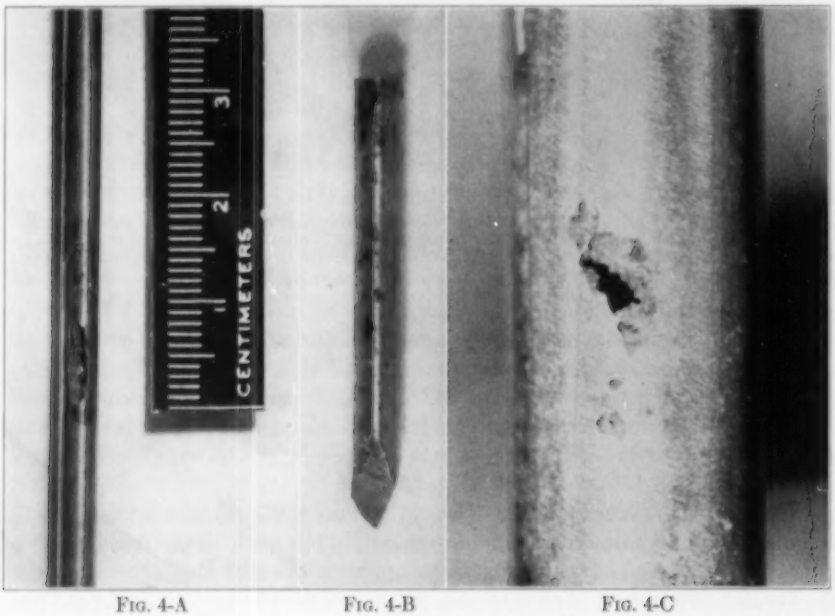

FIG. 4-A FIG. 4-B FIG. 4-C

Figs. 4-A, 4-B, and 4-C: Three views of different parts of the pin to show linear and non-linear pits, general tarnish, and approximate size of the corroded areas. Note absence of pitting in region of the stamp mark in Fig. 4-A.

of these pins were rejected because of improper specifications by the government. The pins were not returned to the manufacturer but evidently were disposed of onto government surplus dealers''. Consultation with the Military Medical Agency revealed that no records are now available concerning the reasons for rejection of

individual lots of surgical items prior to the establishment of the Agency. It was further learned that reasons for rejection included many factors unrelated to the cause for metallic failure in this case—for example, improper dimensions or improper packaging. Since it could not be determined with any degree of assurance that either the pin in question was actually rejected or was accepted and then disposed of as surplus, further investigation of the origin and channels of procurement of the pin was impossible.

The pin was subjected to chemical analysis by two methods—by x-ray fluorescence qualitatively and quantitatively, and by colorimetry (American Society for Testing Materials). The qualitative tests revealed iron and chromium to

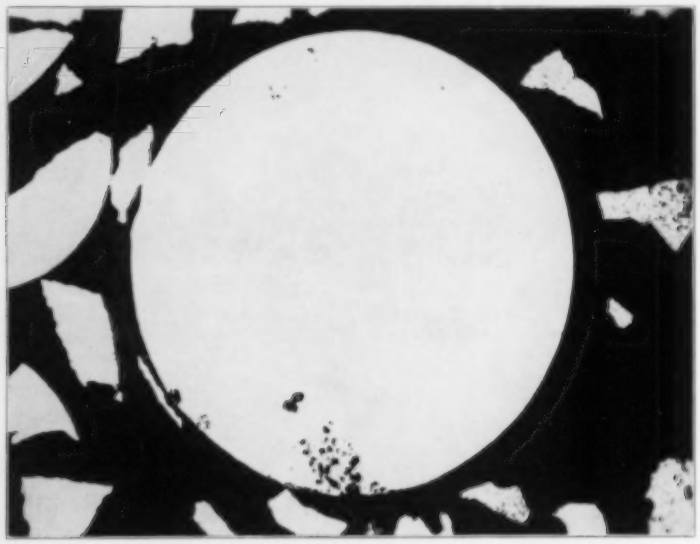

FIG. 5

Cross-section of pin (white circle) embedded in bakelite and before etching shows corroded region at the bottom filled by bakelite embedding medium. Non-metallic inclusions are shown as black granules inside the circle at the top, not in continuity with the periphery. White blocks in the bakelite represent additives to the embedding medium for more rigid support. Cross-section should be a perfect white circle, if specimen is without corrosion or non-metallic inclusion (× 20).

be the major constituents of the alloy; minor constituents (estimated at less than 0.1 per cent) were molybdenum, zirconium, nickel, and manganese. Quantitative tests by x-ray fluorescence revealed 13.66 to 13.67 per cent of chromium, and 0.40 to 0.39 per cent of carbon. Colorimetric methods yielded similar results. The conclusion was that the composition of the steel would fall into the specifications of AISI type 420.

The Brinell hardness was 500. The pin was magnetic throughout. Section of the pin through the pitted area (Fig. 5) showed, in the section examined, that the depths of the pits was .9 millimeter, approximately one-fifth the diameter of the pin. The corroded areas, when etched in sections, were transgranular and did not follow the granule borders.

DISCUSSION

It is recognized that metallic implants, to possess the requisite degree of resistance to corrosion, should be fashioned from metals or alloys least prone to electrochemical reaction in solutions similar to body fluids. At the present time steels of AISI types 316 and 317 (also known as SMO or 18–8 SMO, and in Great

Britain as En 58 J) are most commonly used for the fabrication of implants, although other steels of the 18–8 austenitic series, other alloys (for example, cobalt chromium alloys such as Vitallium and vinertia), and pure metals, such as titanium and tantalum, are also used. Why then was AISI type 420 used to make the Steinmann pin employed in this case? One of the listed [3] uses of steel type 420 is for cutlery and surgical instruments. It has the degree of hardness needed to form a sharp cutting edge and is sufficiently corrosion-resistant (stainless) to wear well under the conditions of service of surgical instruments. Obviously, its composition will not allow it to remain in contact with tissues for long periods, without appreciable corrosion.

The pattern of corrosion in this pin was interesting in that the highest concentration of pits was on the convex segment of the curvature. Increased susceptibility to corrosion of metals in areas of tension stress comes to mind as one possible explanation of this localization of pitting. However, the location of plastic deformation of the pin (that is, the convexity caused by the stress of insertion) may be only one contributory factor to the localization of pitting. That plastic deformation alone may not be the only factor is shown by the absence of localized pitting or accentuation of tarnish at the stamping marks on the pin (Fig. 4-A), areas where even greater concentration of stress occurred. A more important factor probably is cyclic stress. Where a stress, well below the yield point (point of plastic deformation), is cyclically applied, as in fatigue testing, corrosion will be accelerated. Under the conditions of intramedullary application of the pin, some cyclical (muscular or positional) stresses probably were applied to the area of non-union.

The generalized tarnish and the presence of pits on the pin in areas other than on its convexity indicate general susceptibility of the metal to corrosion by body fluids, accentuated by local factors.

Another interesting feature of the localization of the pitting was the linearity of distribution along the shaft of the pin. This feature may be attributed principally to the localization of non-metallic inclusions in the pin. These are nearly always oriented longitudinally because of the stringing-out of such inclusions during the process of manufacture of the wire from which the pin is made. In this process the wire is drawn through progressively smaller dies to reduce the ingot to wire form. Evidence of the presence of these inclusions in the metal was noted in the cross-sectional metallographic specimen. Non-metallic inclusions are present in practically all steels. Since many pits were found in relation to the pure metal and not to the inclusions, non-metallic inclusions may be regarded as factors contributing to the localization of pit corrosion, but not as the principal reason for its occurrence.

Although the entire tract in the medullary canal of the fibula was not examined grossly and only a small specimen of soft tissue and bone was taken for microscopic study, the area of maximum tissue reaction, as determined roentgenographically, corresponded to the maximum concentration of corrosion in the pin. The amount of corrosion product was, therefore, probably maximum at that site. By definition, corrosion is the transfer of atoms from the metallic to the ionic state. Some of the ions may travel far from their origin, but most of them react with other ions in the medium adjacent to their origin to form relatively insoluble corrosion products, which are usually concentrated at or close to the site of corrosion. The reaction of the tissues to corrosion products includes active phagocytosis by macrophages of the corrosion products (rust). When rust is present in large amounts, the granulomatous reaction is severe and often includes, in addition to macrophages, polymorphonuclear leukocytes. As in any inflamma-

tion, the chronicity and the extent of the reaction determines the degree of localized fibrosis. All of these characteristics of tissue reaction were demonstrable in this case and they led to an important precept concerning tissue reactions to implanted metals: *Where corrosion occurs, the reaction of the tissues to the metal is proportional to the rate of corrosion and to the amount of corrosion product.*

Another question which this case raises is whether the presence of dissimilar metals had any bearing on the corrosion. It will be recalled that the screw was made of AISI type 316 steel, whereas the pin was type 420. If electrolysis (the passage of current between dissimilar metals in the tissue fluids) occurred to a significant degree in this case, one would certainly expect the electrolytic or electrochemical effects on the anodic metal to be located on the surface closest to the cathodic metal. The localization of the pits on the pin at a distance from the screw favors the conclusion that dissimilarity of the metals played very little, if any, part in the corrosion in this case.

During the interval between the removal of this pin and the preparation of this report, a similar instance of corrosion of a Steinmann pin has come to the attention of one of the authors (J.C.). A Steinmann pin with identical stampings was received *. This was inserted into the ulna as an intramedullary rod in April 1953 and had to be removed in February 1960 because of increased pain and swelling in the area. There were signs of corrosion on the shaft, point, and hub of this pin that were identical to those just described. This pin had been inserted into the patient's forearm while he was in military service. This indicates that some pins of this type may still have been in circulation as late as 1953. They may still be available in the surgical supplies of military hospitals and of civilian hospitals utilizing surplus military medical equipment.

A consultation with the Military Medical Agency disclosed that the present specifications for Steinmann pins are those of AISI type 316 steel. One simple method of differentiation between AISI type 316 and type 420 steel is the test of magnetic attraction. The 316 austenitic steel is non-magnetic, whereas the martensitic 420 is strongly attracted by a magnet. Thus, an easy non-destructive way is available to differentiate between these types of steel in operating-room supplies.

Despite the superior cutting edge and greater rigidity of the 420 steel—properties of value in Steinmann pins used for skeletal traction—the markedly superior corrosion resistance of type 316 steel and the lesser tissue reaction to it, make this steel far superior for use as an implant where prolonged contact with tissue fluids occurs.

CONCLUSION

A case report is presented where a Steinmann pin used as an intramedullary rod in a fibula showed marked pitting corrosion and ultimately had to be removed because of tissue reaction. The composition of the steel was the principal factor in promoting corrosion, although cyclic stress and non-metallic inclusions probably influenced the localization of the corrosion process.

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Motor-Unit Action-Potential Counts

Their Significance in Isometric and Isotonic Contractions * †

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The recorded action potential of muscle has found many applications in the medical sciences. It is useful in neurological diagnosis for determining the time of activity of muscle (phasic activity) and for appreciation of the general level of muscular activity. A significant quantitative representation of the electromyogram has eluded investigators seeking a valuable relationship between some form of the electromyogram and muscle tension. The so-called integrated electromyographic curve at times has shown promise of producing this long-sought correlation [2,7]. This expression of the electromyogram, while introducing a neat-appearing analogue curve, has no numerical equivalent to be related directly to the tension developed by the muscle. In its present form of common use, it can be shown to be misleading if not erroneous. If it were possible to count all of the rapidly occurring action potentials found in the electromyographic record of normally contracting muscle, an analogue curve with direct numerical equivalents would result. Such a curve should be very similar to the analogue curve produced by isometric contraction. The aggregate action-potential count of the isotonic contraction should be proportional to the work performed by the muscle.

The normal electromyogram consists of a series of recorded action potentials produced by motor units firing at certain frequencies. Through recruitment, the central nervous system is able to summon the participation of previously idle motor units to increase the strength of the contraction. At the same time, active motor units may increase their frequency of firing [1]. Since the individual motor unit is thought to behave according to the all-or-none law, the resulting tension of contracting muscle may depend on the total number of action potentials produced. Total, or analogue, counts of action potentials should represent values proportional to the muscle's tension, if all action potentials represent equal contributions to the tension developed by the muscle. As tension increases, it is not known whether increase of action-potential count by recruitment of additional motor units or by increase of the frequency of those already in action will make the greater contribution to tension. Many of the motor units functioning are in, or near, a state of tetanus.

There is evidence that the axons penetrating the muscle vary in diameter [5]. This suggests that their motor units are of varying size and are composed of different numbers of muscle fibers. Resulting action potentials of motor units would also be expected to vary in magnitude. It is likely that fibers of adjacent motor units interdigitate with the one producing a given action potential, thus influencing its form. It is also considered possible that all of the fibers of the given motor unit are not in a single bundle at one site in the muscle. Thus, each action potential does not bear the same significance regarding its contribution to the total

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tension developed by the muscle. However, if it were possible to obtain action-potential counts from significantly large volumes of muscle, the frequency recorded would be representative of that found throughout the muscle.

Certain electronic counters readily yield action-potential counts, or values proportional to the counts. One may ascertain the count per unit time, or the total count for a single contraction. It is the purpose of this study to examine these counts and to explore their significance, particularly with regard to their relationship to isometric and isotonic contractions in normal human muscle. Although the density of the normal interference pattern of the electromyogram appears to increase with the strength of the contraction, a quantitative relationship has not yet been demonstrated.

Since the normal electromyogram consists of a series of oscillations of varying amplitude and of more or less diphasic form, special devices must be used to appreciate their aggregate value. A summation is necessary in order to compare the electromyogram with anything with a continuous numerical value, such as tension. One can add the total amount of electrical activity, rectifying the inverted forms, thus producing an average (integrated) curve or employ a method for counting the total number of action potentials. The so-called integrated electromyogram produces a summation curve, each point on which indicates the total electrical activity at that instant. Many of the conventional resistor-condenser integrators commonly used in electromyographic work in reality produce an average curve representing the envelope of the electrical activity of the electromyogram. This curve itself may be integrated by measuring the area included under it. Several excellent studies were performed in which the integrated curve [1,2,7,10] was compared with that of the tension continuously developed by the muscle. Relationships were demonstrated between the integrated electromyogram and tension during isometric contraction, or during isotonic contraction where velocity was controlled. The alternative method of producing a quantitative expression for the electromyogram, in the form of a count of motor-unit action potentials, might be expected to yield values proportional to the percentage of total possible motor-unit activity from a given volume of muscle. If the motor unit conforms to the all-or-none law, the total number of action potentials may be of greater significance than total electrical activity which is a function of amplitude and duration, as well as action-potential count.

METHOD

A continuous oscilloscope tracing of action potentials from contracting human muscle under various conditions was recorded. The action potentials were counted by the electronic counter which was fed by the vertical signal output of the oscilloscope. In making such counts, it was possible to record full ten-second intervals, or to record continuously for 0.1-second or one-second intervals. A second oscilloscope tracing simultaneously recorded the conventional electrical average curve of the electromyogram. The average or integration curve was recorded in this study only for purposes of comparison with the analogue count-rate curve which we consider a superior source of information.

Internal electrodes were used with differential amplification. The subject was grounded. The two electrodes were made from 0.006-inch varnished copper wire. One-half inch of the tips was bared. The electrodes were oriented longitudinally in the muscle a considerable distance from the motor point.

There are difficulties in obtaining accurate readings of the absolute tension developed by muscle. Since muscles in the body are attached, usually to bone, their ends are inaccessible for tension studies. Animal experimentations on

muscle tension have usually consisted of laboratory measurements made on stimulated muscle, a situation hardly comparable with tension developed by voluntarily innervated muscle in the unanesthetized subject. Theoretical calculations were made concerning forces developed by muscles in their normal position in man. These theoretical calculations indicated that muscle is capable of surprisingly high tension. In the present study, a technique is employed by which the tension of normal, voluntarily contracting muscle can be measured directly as though the muscle end or its tendinous insertion were free.

The tension developed by the muscle was continuously recorded from a precision force gauge (Fig. 7). Rigid attachment to the force gauge was assured by the use of a calcaneal Steinmann pin representing the insertion of the soleus muscle (Fig. 1). In order to ensure absolute immobilization of the tibia, a

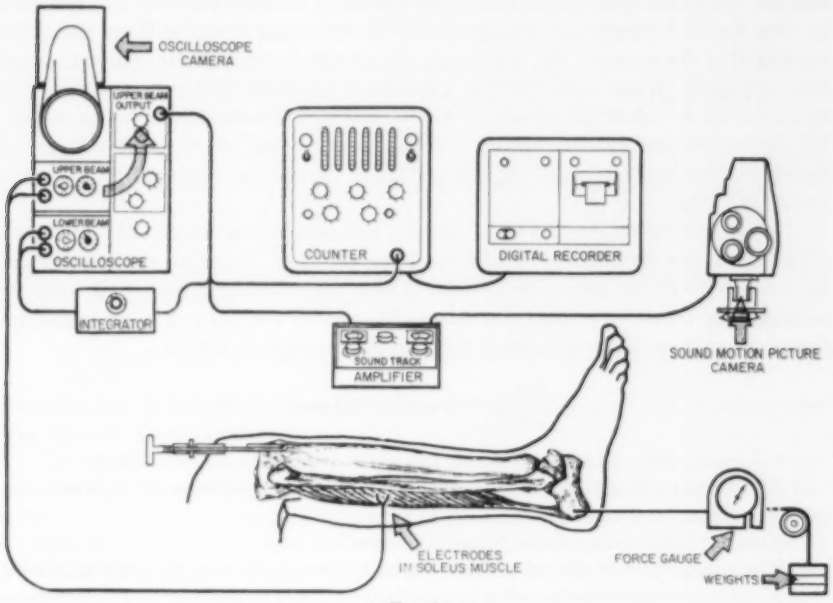


FIG. 1

Experimental diagram for isometric and isotonic recordings.

second Steinmann pin was used. This pin was placed through the tibial tuberosity and secured by a Zimmer clamp to the apparatus. The ability of the soleus muscle to develop tension could be readily appreciated by this direct method.

In laboratory preparations, muscle can shorten a greater amount when detached at one end than when limited by the skeletal system. The bone-pin technique used in this study permitted shortening and lengthening within the muscle's physiological dimensions only. This experimental arrangement (Fig. 1) yielded the following information: (1) continuous electromyogram, (2) action-potential count, with print command and count signal (Fig. 2), (3) electrically averaged electromyogram, and (4) continuous readings of muscle tension developed, as indicated by the force gauge.

Recordings were made for single isometric and isotonic contractions for 10-second intervals and for continuous contractions at one-second and 0.1 second intervals (Figs. 4, 5, 6, and 8). The knee was flexed to 90 degrees to eliminate any possible participation of the gastrocnemius muscle. It was believed that the

soleus muscle was virtually isolated by the use of the calcaneal-pin technique. The calcaneal pin was placed near the muscle's insertion. Relatively young, active individuals were used as subjects. The procedure was carried out six times. Fifty to sixty contractions were recorded at each test. Isometric tests were made at various muscle lengths and isotonic tests were made. With practice, the peroneal and posterior tibial muscles were easily suppressed. In one experiment, any contribution of the peroneal muscles was definitely excluded by block of the common peroneal nerve. The force gauge used measured a considerable amount of force with a negligible amount of excursion, thus permitting measurements of near isometric contractions. Continuous readings from the force gauge were made by the use of the sixteen-millimeter sound camera, the sound track of which recorded the electromyogram in synchrony with the oscilloscope and oscilloscope camera. For exact synchronization of the period of activity counted and recorded by the digital recorder, it was necessary to introduce a signal from the print command of the counter. By this signal, the precise instant of the count recorded was indicated. When counting for 1.0-second intervals, the counter yielded a count for every other full second. When recording 0.1-second continuous counts, the figure printed by the digital recorder represented every third 0.1-second interval. The count signal (Fig. 2) indicated the precise instant at which the count was made.

When recording from normal muscle, the oscilloscope sensitivity used was 1.0 millivolt per centimeter. In addition to this setting, it was necessary to adjust the sensitivity of the electronic counter. Using the standard input of the counter at maximum sensitivity, the pulse threshold counted was 0.2 volt. This minimum threshold value may be expressed in terms of the original signal:

$$\frac{0.2}{2.0} \times 1.0 \text{ m.v.} = 0.1 \text{ m.v.}$$

0.2 volts represents the counting threshold of the electronic counter.

2.0 represents the vertical signal output of the oscilloscope in volts per centimeter of oscilloscope deflection.

1.0 m.v. is the oscilloscope sensitivity used.

The magnitude of the minimum counting threshold was thus 0.1 millivolt.

Thus, the counter included very small oscillations in the count. It was recognized that this might not be the ideal sensitivity at which to count action potentials. It was further recognized that such a sensitivity might give a very misleading count in certain pathological conditions such as muscular dystrophy in which there are many action potentials of low magnitude, but in which the muscle is obviously weak. Settings must be determined for the counter to be used as standards in poliomyelitis, muscular dystrophy, and normal muscles. Since motor units of various normal muscles vary in size [6], action potentials of different magnitude result. Also, the aggregate count found in normal muscle varies since the number of motor units per unit volume varies from muscle to muscle throughout the body.

The procedures in which tension was recorded were done only on normal subjects. However, action-potential counts were recorded from a variety of subjects with pathological conditions, such as poliomyelitis, muscular dystrophy, and amyotrophic lateral sclerosis.

An alternative counting threshold was available by use of the discriminator. This adjustment of the counter made it possible to set the count threshold at selected values. Thus, counts could be produced representing either positive or negative potentials exceeding a certain value. The smaller components of the motor-unit complex could thus be eliminated from the count. However, many

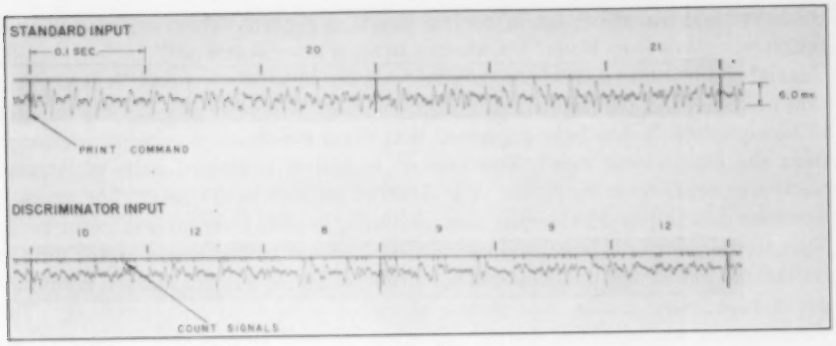


FIG. 2

Sample continuous counts: standard input, discriminator input.

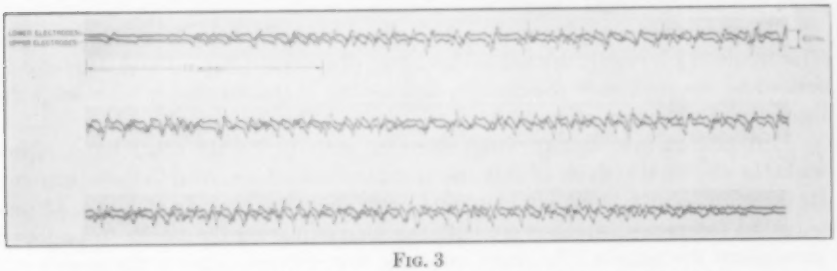


FIG. 3

Synchronization during voluntary contraction, dual recording electrodes.

potentials low in amplitude because of their distance of origin from the electrodes (Fig. 2) were also excluded.

The question arose, how typically is the muscle actually represented by the two electrodes from which the count is taken? Would electrodes placed in other parts of the muscle convey a comparable record? On occasions, using normal subjects, several pairs of electrodes were inserted, each pair of electrodes being inserted transversely in the muscle. The tracings of Figure 3 were taken from the upper and lower portions of the anterior tibial muscle and recorded simultaneously from a dual-beam oscilloscope. The recording was made at a camera speed of twenty inches per second. It is apparent that during most of the recording, the traces from the upper and lower portions of the anterior tibial muscle are remarkably similar. The phenomenon of synchronization appears at times to be almost complete for a considerable portion of the muscle and leads one to question the mechanism of recruitment as one of the means of increasing the strength of contraction. How could recruitment take place at precisely the same rate at different portions of the muscle? It appeared that contractions of even moderate magnitude were likely to involve the entire muscle, with all of its motor units participating at approximately the same rate. Identical, concurrent pulses are often found at various portions of the muscle during a contraction of moderate to large magnitude. In the presence of such complete synchronization, increase in frequency becomes a more important mechanism than recruitment for increasing the strength of contraction. If recruitment were the important mechanism, its effect could hardly result in identical changes in the oscillograms of volumes chosen at random throughout the muscle, unless its effect were quite uniform throughout the muscle.

Synchronization was described by Buchthal and Madsen in 1950 and by

Buchthal and his associates in several previous reports. They recorded similar action potentials from leads from various parts of normal and pathological muscle. Coaxial and bipolar electrodes separated by 0.2 millimeter were used. Synchronization was observed, particularly on maximum effort, when recruitment was thought to be complete. It has been suggested that these synchronous records originated from the same motor unit [8]. The present technique employed pairs of internal electrodes made from varnished wire 0.006 of an inch in diameter. The exposed tips were one-half inch in length, thus producing records from several motor units. This technique would not produce records confined to the single motor unit in normal muscle, except under special conditions when the subject exerts a minimum contraction. This means that groups of motor units fired simultaneously. The phenomenon was observed during moderate, as well as maximum, contractions (Fig. 3). By the use of dual internal electrodes, oriented transversely in the muscle, synchronization was observed throughout one-third of the recordings from the anterior tibial muscle.

There is often a predominating action-potential frequency in skeletal muscle. This frequency is closely related to the degree of contraction produced. It is closely related to the tension of the muscle, and counts of this frequency vary with the intensity of the contraction.

Integration (averaging) of the electrical activity, on the other hand, represents the electrical activity of only the amount of muscle exposed to the electrodes. It, therefore, is not so closely identified with whole-muscle behavior as is action-potential frequency, which represents the predominating frequency to be found throughout the muscle. The study indicates that different sites in the muscle will yield comparable counts.

The action potential, having frequency, amplitude, duration, and fine variations in form, is influenced by the adjustment and calibration of the equipment used. Standardization of results depends on control of the many technical factors governing the size and form of the action potential. In this study, uniformity of many of these variables in technique was established. It was thought that the most important factors were:

1. Caliber of electrode, length of tip (the number of motor units contributing to the recording is subject to the diameter and length of the exposed tip);
2. Distance between electrodes;
3. Sensitivity settings of recording apparatus (oscilloscope and counter);
4. Uniformity and standardization of speed of the recording equipment;
5. Proper setting of counting voltage threshold;
6. The use of equipment of suitable frequency recording range [4].

By using large dual electrodes, as in this study, a larger volume of muscle was sampled than by using a single coaxial electrode which may confine the recording more or less to the activity of a single motor unit. On the other hand, surface electrodes are thought to record from a large mass of muscle but with less specificity. Surface electrodes were found to yield a lower action-potential count than internal dual electrodes. Accordingly, dual internal electrodes placed one inch apart with 0.5 inch of the electrodes bared were used. Their orientation was horizontal, although transverse orientation gave comparable results. The behavior of this volume of muscle was considered characteristic of the muscle, because of the consistency found in count and in the appearance of action potentials in repetitive tests made in different regions of the muscle, and the striking similarity of the action-potential curves often recorded from different portions of certain muscles during the same contraction (Fig. 3).

By using dual internal electrodes and differential amplification, with the

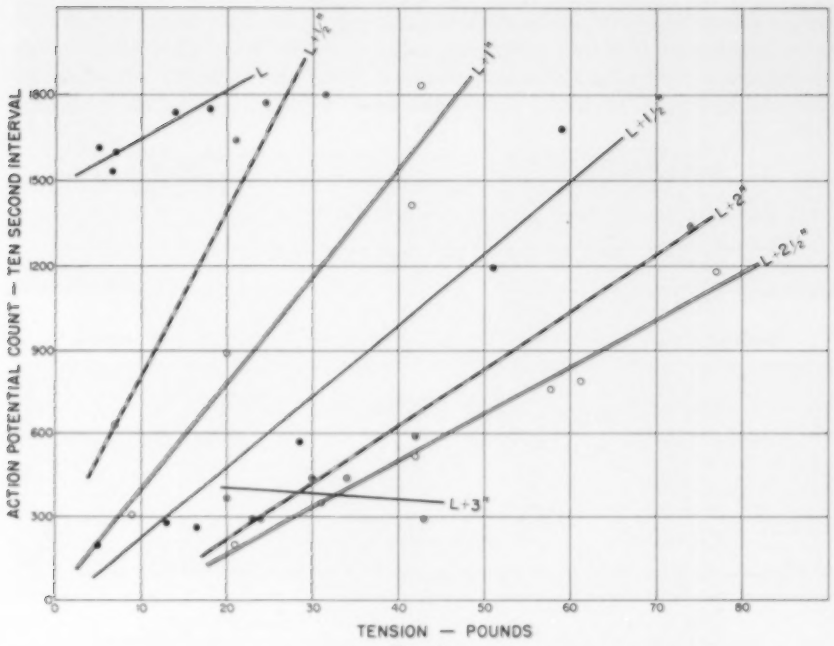


FIG. 4

Ten-second isometric contractions.

subject grounded to the apparatus, one records the difference in potential at the two electrodes. Thus, one may record motor-unit action potentials from either electrode, or action potentials at each electrode may be combined. Conceivably, potentials of opposite sign may simultaneously occur at the two electrodes and thus cancel each other. However, there is almost always a sufficient time interval between action potentials for at least part of each to be recorded on the oscilloscope and to be counted by the electronic counter.

RESULTS

Total counts of ten-second isometric contractions were plotted against tension as demonstrated in Figure 4. Since these contractions were studied at various muscle lengths, several graphs were prepared. As the contractions increased in tension, a number of readings were recorded at each length. The data for each length demonstrated a linear relationship between total count and tension. In this diagram, it must be noted that to place the muscle at progressively greater lengths, it was necessary to stretch it or apply tension to it. This tension, called the passive tension, has been subtracted from the recorded tension in the values used in this figure. The values given for tension are, therefore, the developed tension for each contraction. The portion of the theoretical length-tension diagram[11], in which the muscle lengths of Figure 4 are to be found, is indicated in Figure 13.

The continuous 0.1-second-interval counts are demonstrated in Figures 5 and 6. These are records of isometric contractions, and the relationship of count rate per unit time to tension is demonstrated. The similarity of the two analogue curves is noted. It is also noted that the count-rate curve precedes that of tension. Since the count rate given for each point plotted on the curve is instantaneous and

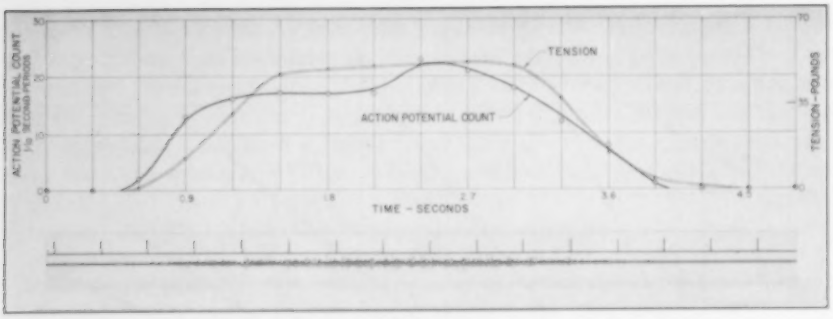


FIG. 5

Analogue curves, tension, and 0.1-second action-potential counts (print command).

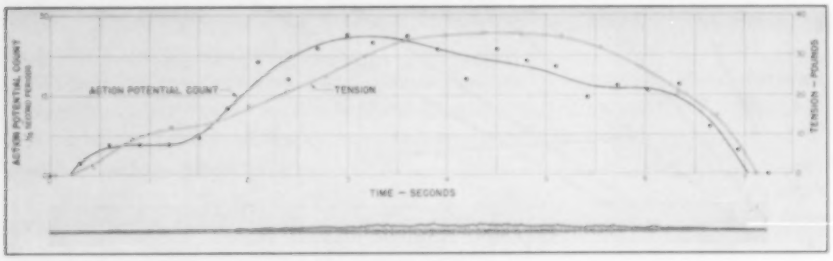


FIG. 6

Analogue curves, tension, and 0.1-second action-potential counts (integrator).

is indicated by the print command (Fig. 5), there is no lag due to apparatus. The actual delay between tension and count rate then, as indicated, is physiological. The counter, unlike the integrator (averager), does not have significant time delay. The resulting analogue curve of count rate per unit time is somewhat similar to the average curve. However, any point on the count-rate analogue curve has a definite numerical value. This value represents frequency of firing of motor units at the point under consideration for the volume of muscle immediately surrounding the electrodes. Figure 6 represents an analogue count-rate curve compared to the force curve and to the integrated electromyogram. Since no print command is recorded here, synchrony is not considered absolute. However, the 16-millimeter sound camera used can be demonstrated to operate at precisely twenty-four frames per second (by use of a known frequency from the counter). Since its sound track consists of an audio recording of the signal counted, the analogue curves of action-potential count rate and tension may be very accurately matched. One can thus compare count rate, tension, electromyogram, and integrated electromyogram for a complete contraction. Such a contraction is shown in Figure 6.

Isotonic curves of contractions with progressively increased loads were recorded (Fig. 8). Here, tension was not recorded and the pin technique was not used. An attempt was made to have the subject perform the contraction as uniformly as possible. Approximately the same velocity of contraction was used for each contraction. As the load was progressively increased, action-potential count rate similarly increased. The count rate, a function of reinforcement and frequency variation of action potentials, closely followed variation in load. The leveling off of the curve as the load is increased indicates that as the contraction approaches its maximum there is increase in synchrony of motor units. This synchrony results in a lower count than would be anticipated.

By the use of planimetry, the areas of some of the averaged curves of complete contractions were obtained. The area thus obtained represents actual integration of the electromyogram. Several consecutive isometric contractions of gradually increasing intensity were made, the total action-potential count

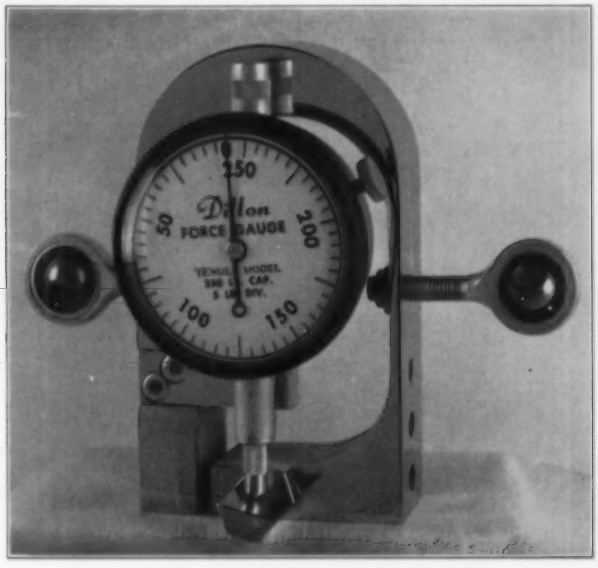


FIG. 7

The Dillon force gauge used for isometric measurements.

recorded, and the area of the average curve plotted against total action potential (Fig. 10). These contractions were of moderate intensity and were performed under similar conditions. The linearity of this relationship for normal muscle is evident. Since, throughout the body, the muscles have motor units of various size[6] graphs of different slopes would be expected. A different slope of the resulting line is also anticipated for pathological muscle. A future study is planned in which a real integrator is to be employed. Such an integrator will actually indicate total electrical activity for a given contraction or for a given portion of the electromyogram.

Investigations were done in which the average electromyogram, and total count were recorded in such pathological states as poliomyelitis, muscular dystrophy, and amyotrophic lateral sclerosis. It was not possible to record tension in these studies; instead, maximum contractions were used. These are to be considered preliminary studies. They were performed both with dual internal wire electrodes and with the coaxial single electrode. Such studies served as a basis for comparisons with normal muscle used later in this report.

DISCUSSION

The electronic counter accepts and counts pulses of extremely fast rise time. It is capable of counting over a million pulses per second. Muscle action potentials are of a much lower range of frequency. Since the action potential is produced by the motor unit, each of its fibers contributing, the question arises whether the counter might consider each fiber's action potential an individual pulse. This possibility can be eliminated by proper threshold setting of the electronic counter.

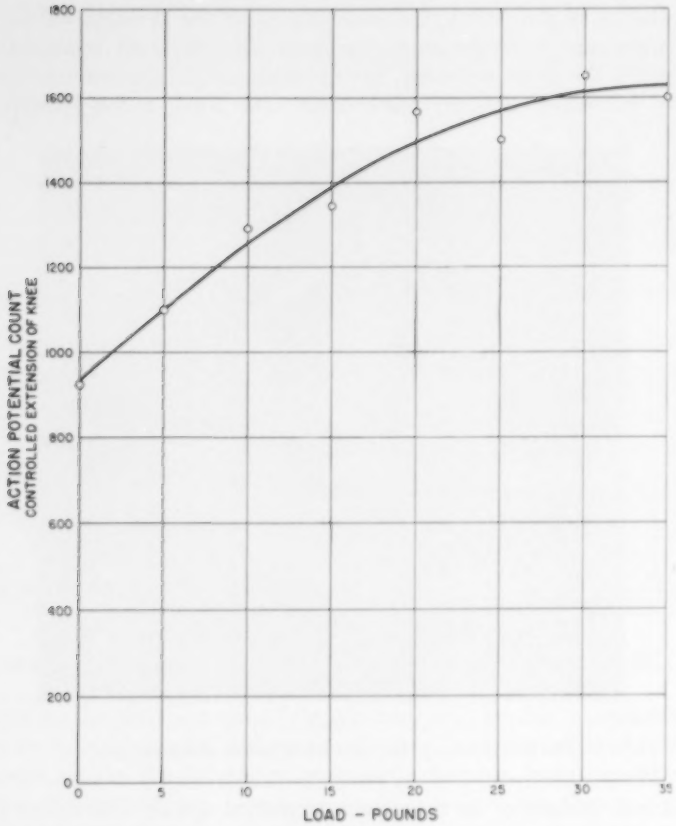


FIG. 8

Isotonic contractions at controlled rate, with increasing load.

Thus, if the possibility exists that firing of the fibers of the motor unit are not absolutely synchronous, individual fiber amplitude would not be of a sufficient magnitude to be counted. Figure 2 demonstrates that the counter actually counts only motor-unit action potentials. The threshold of action potentials counted can be conveniently selected by use of the discriminator.

The ten-second isometric contractions and the analogue displays of the 0.1-second-interval counts demonstrate a linear relationship between count rate per unit time and tension. At a given muscle length, the maximum action-potential count rate can be predicted.

The impulses from the tendon afferents are thought to be responsible for reducing the electromyogram under conditions of stretch [9]. Muscle spindles and other proprioceptive organs, such as the Golgi apparatus, influence the contraction. Thus, any measurements of tension in muscle must be made under certain conditions and those conditions precisely recorded. The isotonic contractions described by Bigland and Lippold were made under specified conditions, the muscle being required to perform a task in which shortening was at a measured velocity. In isometric tests, initial length and tension are of similar importance. Figure 11 shows the effect of initial length and passive tension on action potential.

Obviously, the behavior of muscle is influenced by the load to which it is subjected. Contractions of the soleus muscle during walking involve very little

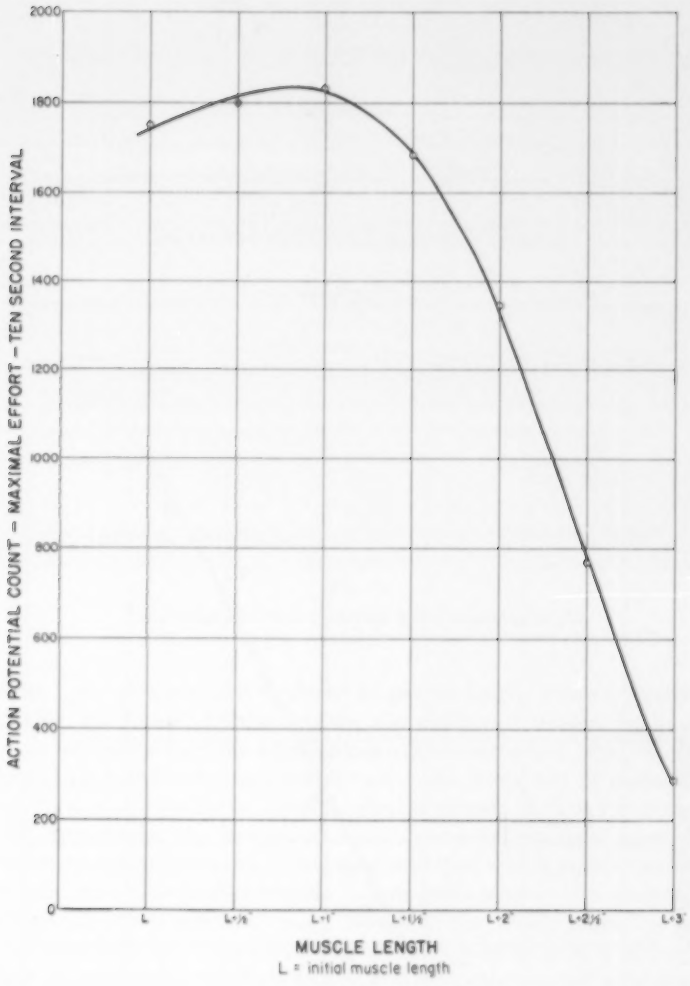


FIG. 9

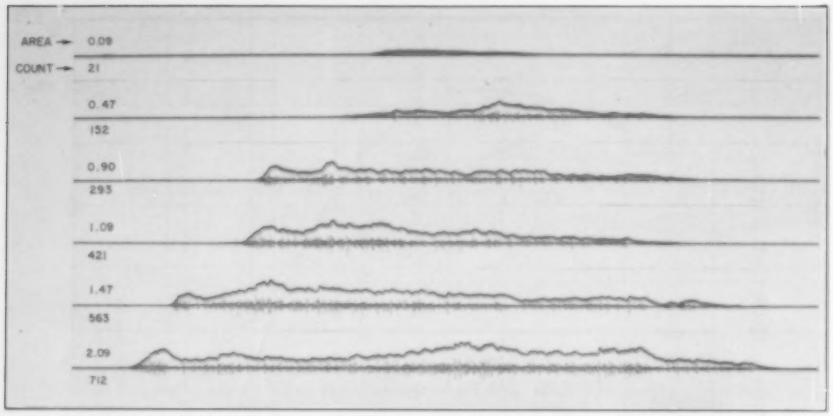
Action-potential count *versus* length.

change in length, and great tension may be possible although the action potentials are of moderate amplitude. High action-potential counts may develop in the non-loaded muscle with very little resulting tension since the contraction is unopposed.

The bone-pin technique used to record tension eliminates the very difficult task of correcting for the leverage systems of joints. Unless the muscle end is free, or bone-pin techniques are used, muscle tension cannot be measured without elaborate leverage-system calculations.

Action-potential count rate is a function of recruitment and frequency of motor-unit contraction. The counter is unable to identify the source responsible for increase in rate. Which is the more important source, recruitment of new units or increase of the frequency of units already in a state of contraction? Does recruitment of a new motor unit produce more change in total tension than increase of the frequency of one already in a state of tetanus, or near tetanus?

Isometric tension and count rate relationships are linear (Fig. 4). Each muscle length is a separate consideration. Paradoxically, the action-potential



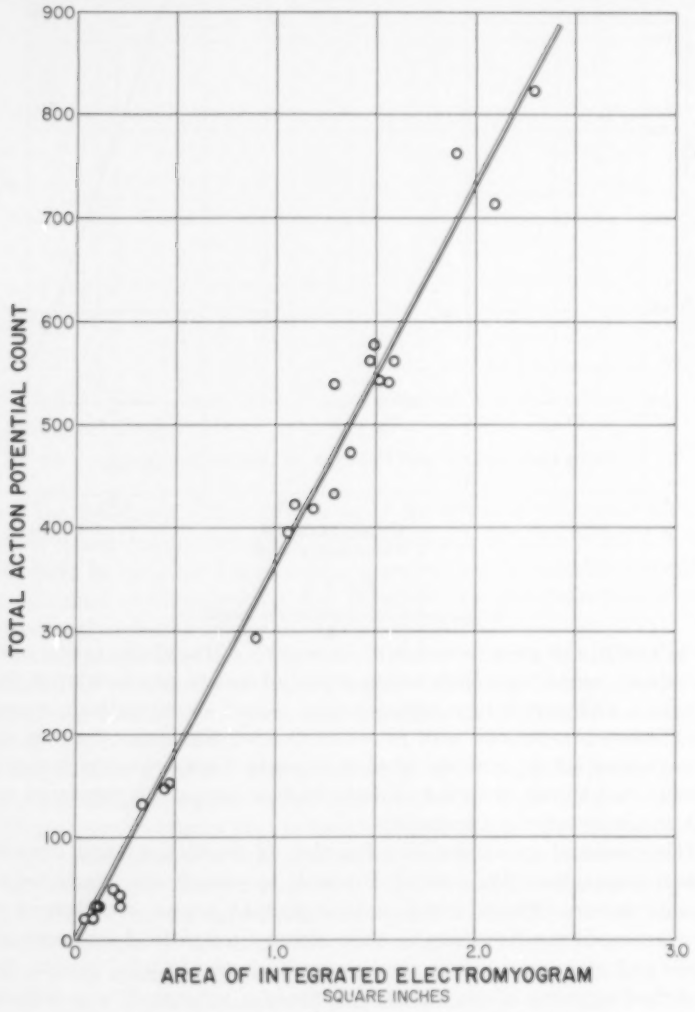


FIG. 10

Integrated average curve *versus* total count.

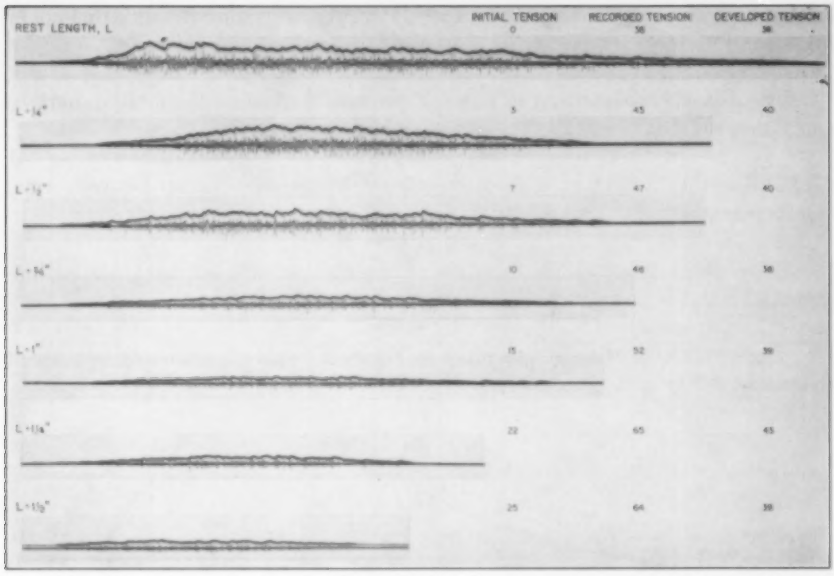


FIG. 11

Diminution of action potential with increasing length.

counts are lower as the muscle is placed at greater length where it develops more tension (Fig. 9). At still greater lengths, the developed tension finally becomes smaller, as the right side of the length-tension curve is reached (Fig. 13). If tension is increased by recruitment and by increasing the frequency of motor-unit contraction, how is it possible to develop greater tension with a lower count rate (Fig. 4)? Apparently, the motor-unit action potential does not have the same significance at different lengths. It might be said that within certain limits, muscle is more efficient at its greater lengths—when great tension is accompanied by a low motor-unit action-potential count. However, the muscle must first be placed at such a length by its antagonist or by an outside force such as gravity. Work must first be done on the muscle before its greater tension output at greater length is possible.

The single electrode with a very small tip or the coaxial electrode may be used to obtain recordings from a single motor unit. The motor unit near its maximum contraction is expected to be in complete tetanus, at which time its tension curve reaches a plateau (Fig. 8). Hence, an increase of count recorded by a coaxial electrode indicates an increase of individual motor-unit frequency, whereas an increase of count recorded by dual electrodes indicates both reinforcement and increase of individual motor-unit frequency.

Thus, action-potential counts are proportional to tension until the maximum tetanus frequency of all the motor units is reached. The isotonic contractions in Figure 8 reach this stage, the curve leveling off. The isometric contractions in Figure 4 are of lesser magnitude. Here, the action-potential count-tension curve is linear throughout. Linear relationships to tension for isotonic, as well as isometric, contractions are expected if the contraction is regulated and does not exceed a certain limit. No relationship is expected for small loads or rapid spring-loaded contractions.

The isometric contraction (Fig. 4) performs no work since there is no change

in muscle length. Here, tension is directly related to action-potential count or frequency:

$$C \backsim T$$

The isotonic contractions in Figure 8 produce work since the muscle shortens and lifts a weight:

$$W = T \times D$$

The results in Figure 8 show an almost linear relationship between total action-potential count and work:

$$C \text{ (Count)} \backsim W$$

Since distance, as well as duration of contraction, was constant, the action-potential count is proportional to average tension:

$$C \backsim T$$

The terminal portion of the curve in Figure 8 levels off, probably because of increasing motor-unit synchronization as the strength of contraction increases.

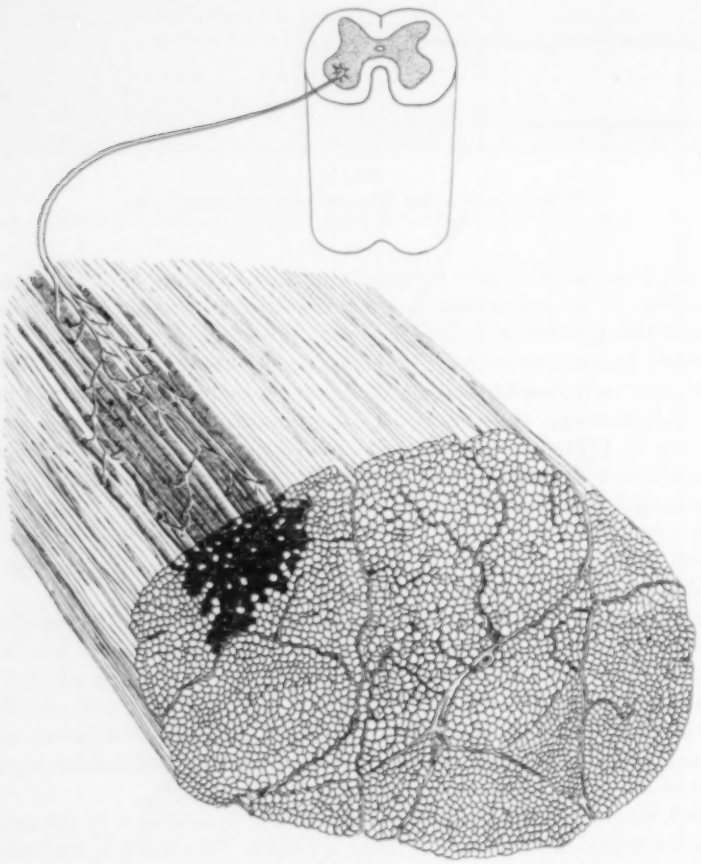


FIG. 12

Diagrammatic representation of the motor unit and the components of the final common path.

SUMMARY AND CONCLUSIONS

Muscle action-potential counts may be conveniently recorded by electronic counters. Total counts for a chosen time interval may be recorded, or a continuous count (analogue display) may be recorded. Total counts and analogue displays

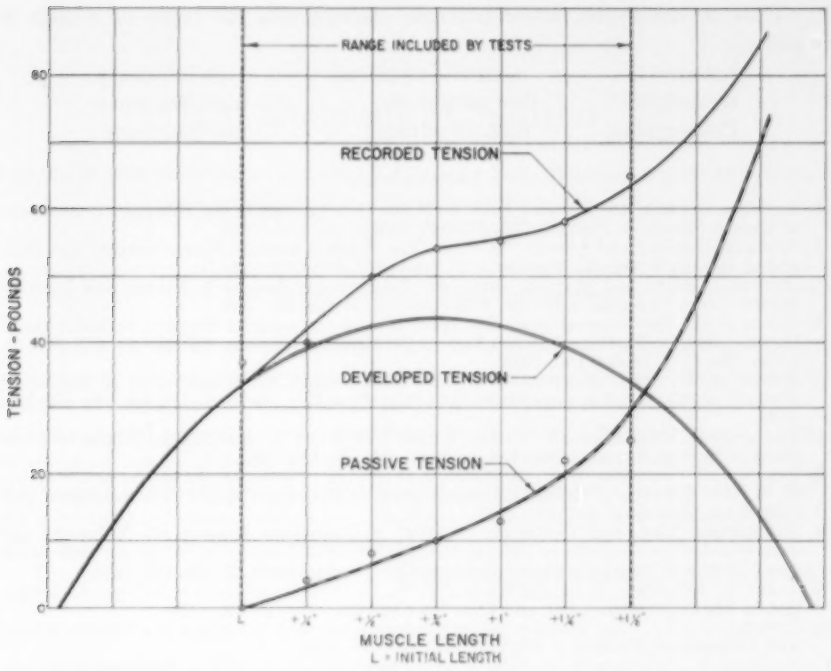


FIG. 13

Theoretical length-tension diagram, normal range of muscle length used in tests of Fig. 4.

for muscle contractions make possible a numerical representation of action potentials produced by a given volume of muscle. The integrated (averaged) curve of total electrical activity may thus be replaced by the action-potential count of the electromyogram having a total, or continuous, numerical expression. For muscle-function analysis and locomotion studies, the continuous action-potential count with established threshold values, adds significantly to the information gained from the conventional electromyogram.

The time constant of conventional electrical integrators, due to dependence upon capacitors, is overcome. A definite delay in the rise of tension following the appearance of the rising action-potential count is observed (Figs. 5 and 6). The electromyogram, its count rate and averaged form, decline well in advance of tension.

Total counts for ten-second periods of activity increase in linear fashion as the strength of the isometric contractions increases. A skeletal-pin technique has been used for accurate measurements of muscle tension. The range of muscle length studied is limited by physiological joint ranges of motion. Thus, only the central portion of the theoretical length-tension curve, the physiological portion, has been studied.

The continuous action-potential count is related directly to tension during isometric or isotonic contractions as long as the muscle is loaded.

The electronic counter appears to have great possibilities of application in the study of neuromuscular disorders. Since different adjustments of both the oscilloscope preamplifier and the counter are necessary, results are not directly comparable with recordings from normal muscle. However, normal, dystrophic, and poliomyelitic muscle have definite characteristics of action potential, frequency, and amplitude.

Thus, a motor-unit action-potential classification for types of muscle is possible:

Normal	moderate amplitude	high frequency
Dystrophic	low amplitude	high frequency
Poliomyelitic	high amplitude	low frequency

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Hip Shelves in Children*

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Results of the hip-shelf operation have been reported in the past. Highly disapproved of at one time by one of the authors, the procedure has been gradually accepted as logical in certain situations after the method of implanting the shelf had been revised and improved. After many years we wish to determine: (1) the usefulness of the procedure; (2) the permanency of relief supplied; (3) any disadvantages consequent to its use; (4) growth, absorption, or displacement of the shelf after long follow-up; and (5) any changes in the acetabulum, pelvis, or upper part of the femur induced by the presence of the shelf.

The present paper is a corollary to a paper on the use of the hip shelf in the adult.

CASE MATERIAL

This report is based on a consecutive series of sixty children, on whom eighty-two shelf operations were performed at four different hospitals. Shelves were applied to both hips at the same operation on four occasions. The ages of the children when the shelves were applied ranged from one to fourteen years, an average of 4.6 years. Of the sixty children studied—seventeen boys and forty-three girls—there were fifty-six white, one Puerto Rican, and three Negro patients. Twenty-two were under private care and thirty-eight were on ward service. Both hips were involved in seventeen patients. Of the forty-three patients with one hip involved, twenty had involvement on the left side and twenty-three on the right.

The diseases causing the hip disability in the sixty patients were: congenital dislocation of the hip in thirty, congenital subluxation of the hip or coxa magna in seven, cerebral palsy in three, poliomyelitis in twelve, old suppurative arthritis in six, and meningomyelocele in two.

The hip disabilities for which the eighty-two shelf operations were indicated were: dislocation, six procedures; subluxation, twenty-three; aplasia of the acetabulum, forty-seven; absorption of a previously applied shelf, five; and coxa magna, one procedure.

The period of follow-up of these procedures ranged from two to twenty years, an average of 6.3 years. The ages of the patients at follow-up ranged from four to thirty-three years, an average age of 10.9 years. Only ten patients (eleven hips) are over sixteen years of age. Further changes, due to growth, may occur in the others.

Treatment of an unstable hip by shelf operation is contra-indicated in a child who does not have sufficient power to control the hip, in a child who has spastic paralysis and cannot use the hip, or in a child who may die of ascending kidney infection before the hip can be used. We have attempted to avoid such cases, but as will be apparent, we failed in certain instances.

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The word *stability* as applied to the hips studied in this series refers only to the relationship between the femoral head and pelvis. Stability in this sense does not take into account the ability of the patient to stabilize the trunk on the lower extremity. Hence, a stable hip in this study is a hip joint in which the relationship of the femoral head to the acetabulum is maintained during stress and during weight-bearing, even though the patient has a limp and a positive Trendelenburg test owing to muscle weakness.

PREVIOUS TREATMENT

Many of these children had had numerous other operative procedures for the treatment of their hips (congenital dislocation) and for the care of other pathological lesions not directly associated with their hip disease (poliomyelitis and cerebral palsy).

Prior to the shelf operation, there had been forty-four open reductions and twelve closed reductions of the hip. In some patients these procedures had been done repeatedly on the same hip. Thirty-four derotation osteotomies had also been performed.

Abduction braces (for example, Denis Browne, Colonna abduction apparatus, Frejka splints, triangular pillows, and plaster retention apparatus) had been used extensively prior to the shelf operation, but no preoperative supports were used by us in preparation for operation. Nor were other preoperative measures employed, such as traction, manipulation, or additional physical measures. In those hips where frank dislocation was still present and the patient's age contraindicated reduction, no traction was applied, on the assumption that the head of the femur was already in the most favorable position for support by a shelf. Traction displacing it downward could only place it in a potentially less stable position. The shelves were applied in each instance above the femoral head with no attempt to change the position of the head.

OPERATIVE TREATMENT

Development of the Procedure

Three of the children included in this series (five hips) had shelf operations prior to 1946. In these patients the shelves were formed by attempting to turn down a section of the outer cortex of the ilium, sewing it to the outer end of the capsule. Four of these five shelves broke free of the ilium at their bases and this area was reinforced with cancellous bone obtained locally from the ilium at the same operation. All these grafts eventually united to the ilium, but above the level originally planned, with the result that their bases were well above the acetabular margin. These grafts were located in the soft tissues above the femoral head with only their tips in contact with the capsule. All these grafts absorbed, more or less, and in two the distal ends of the graft pulled away from the capsule. The results in two of these five hips (both in the same patient) were good. Both of these grafts bent downward to just above the acetabulum. Although both of these shelves absorbed and the remaining stubs of the grafts were displaced upward, the acetabula deepened and thus the margins projected laterally because of the widening of the ilium above the acetabulum. This secondary change in the acetabula in these two hips was responsible for the satisfactory results. In the remaining three hips the shelves absorbed, their remnants moved upwards, and the acetabula remained inadequate in size in relation to the femoral head.

In 1937, in a child, fourteen years old, with a true congenital dislocation of the hip (Fig. 14), we performed the first shelf operation of the type now used. In this instance a slot was cut through the ilium above the dislocated femoral

head to receive the proximal end of the graft; the distal end was placed beneath the gluteus medius and minimus muscles. This hip was stable and painless twenty years after operation.

This result led to the development of the present technique.

Present Technique

There are two points in which the technique for the shelf operation in children varies from that in adults (Figs. 1-A and 1-B). First, the iliac crest in children consists of the iliac epiphysis. This epiphysis should be pushed off from the ilium before the shelf is cut from the external table. The epiphysis can then be replaced after removal of the graft. No defects in vertical growth of the ilium have been

FIG. 1-A

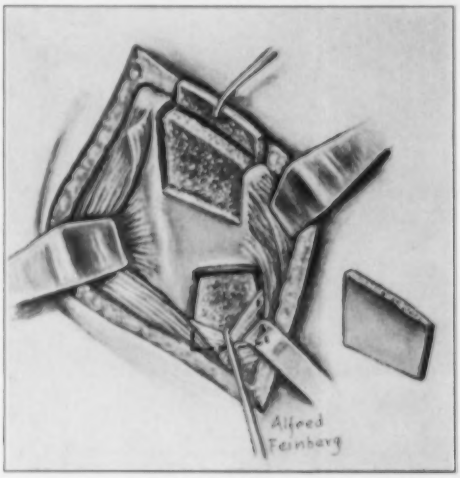

FIG. 1-B

Technique for removing and inserting the graft. See text for description of the operative technique.

noted to result from this procedure. Secondly, the shelf should be implanted as low on the ilium as the femoral head will permit and not slanted as obliquely downward as in the adult. To describe the procedure briefly: A roughly rectangular graft, narrower at one end than at the other (Figs. 1-A and 1-B), is removed from the upper portion of the external iliac cortex after the hip has been exposed through a Smith-Petersen approach. A slot is then cut in the outer cortex at the acetabular margin, just above the femoral head. This slot is tangential to the superior capsule and slightly posterior to the femoral head. The reflected head of the rectus femoris is partially freed from its attachment to the ilium. The broad end of the graft is placed distally beneath the reflected and direct heads of the rectus and superficial to the intact capsule of the hip joint. The proximal or narrow end of the shelf is then snapped into the slot cut in the ilium. Such a shelf is fixed firmly and needs no retention sutures to hold it in place. The wound is closed in a routine fashion.

Seventy-seven of the shelves were done by this technique since it was first used in 1946. Routine transfusion was used in thirty-three of the thirty-six procedures done at The House of St. Giles the Cripple. No transfusions were given during the forty-six operations at other hospitals. The operative time ranged from twenty minutes to 110 minutes, an average of sixty-four minutes. Operative time was longer in some instances because of resident training, photography, and similar factors.

Twelve Board-qualified orthopaedic surgeons proctored or did these operations. Twenty residents performed procedures under supervision. The results as presented therefore represent diversified surgical ability.

POSTOPERATIVE TREATMENT

Since the present technique became routine in 1946, plaster spicas have been used only for patients with cerebral palsy. Postoperative treatment since 1946 has consisted in merely bandaging the legs together for one to two weeks after

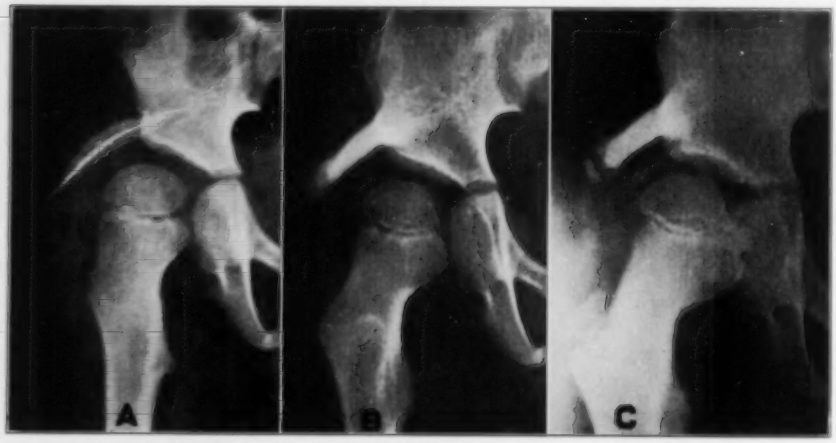

FIG. 2

February 16, 1956 March 6, 1957 February 26, 1960

Paralytic dislocation of the hip due to anterior poliomyelitis in a child two years old. Shelf implantation performed February 15, 1956. Note size and location of the shelf (February 16, 1956). It extends downward, well beyond the head, under the reflected tendon of the rectus femoris; it also pierces the ilium just above the acetabular margin. As time has passed, the non-functional lateral tip of the shelf has absorbed (March 6, 1957). In the last roentgenogram (February 26, 1960) there appears to be an epiphysis on the outer end of the implant. Since the outer end of the graft was originally taken from the iliac crest, this may represent growth of a transplanted portion of the iliac crest. Four years after operation (February 26, 1960) the femoral head has been maintained at the level of the triradiate cartilage, the acetabulum appears to have become deeper, and the superior margin of the acetabulum seems to have enlarged laterally over the femoral head. Widening of the lower ilium and narrowing of the upper ilium seem to have taken place during growth. The shelf has also become thicker and more dense at its base. The roentgenogram suggests that a marrow cavity has developed within the shelf.

operation. After removal of the bandage the children were left free in bed, but weight-bearing was not permitted for an additional two to four weeks. Thereafter, full weight-bearing was allowed. No traction, physical therapy, or manipulation was used after operation, except for the patients with dislocations due to cerebral palsy. In one child whose hip dislocated four years after onset of poliomyelitis, the shelf broke and the hip redislocated. It was pulled back into place by traction on the leg (Fig. 3). The shelf subsequently reunited at the original level and provided adequate support for the hip.

COMPLICATIONS

Immediate Postoperative Period

There was one death from postoperative aspiration of vomitus, as proved at autopsy. (We never were able to find out how the child obtained the food.) There were no other early complications, except maceration of one wound in relation to the silk sutures in a child. This wound healed in less than one week. Postoperative roentgenograms showed that in sixteen procedures the shelf appeared to have been

inadequately placed at time of operation; three were the free-graft or turned-down shelves and thirteen were the slotted, snap-in type. The shelf, as shown in roentgenograms made shortly after operation, should extend well beyond the femoral head under the rectus muscle (Fig. 2). Placement of the slot for the base of the shelf above the acetabular margin in a child will probably end in a poor result. The slot must be cut at the acetabular margin. If the distal end of the shelf does not point in the proper direction, this indicates, we think, that its distal end was not

November 10, 1952 August 28, 1956

November 5, 1956 FIG. 3 September 4, 1959

Paralytic dislocation of the hip in a child, six years old, four years after onset of anterior poliomyelitis. Shelf operation was performed October 2, 1956, at the age of six years. Following implantation of the shelf, the femoral head has displaced no further and even appears to have been replaced slightly into the acetabulum. A fracture of the shelf occurred (November 5, 1956) but this healed while the leg was immobilized in traction.

FIG. 4

February 13, 1953 April 15, 1953 February 19, 1960

Paralytic dislocation of the hip following anterior poliomyelitis. Patient was four years old when the shelf was implanted on March 2, 1953. Shortening of the graft occurred due to absorption of that portion of the shelf which was non-functional (projecting beyond the femoral head). Seven years after operation (February 19, 1960) note shortening of the graft; maintenance of an adequate socket with the femoral head well seated within the acetabulum at the level of the triradiate cartilage; widening of the lower ilium; and narrowing of the upper ilium.

FIG. 5

January 5, 1954 February 6, 1954 February 17, 1960

Congenital dislocation of the hip in a child, four years of age (*A*). Shelf operation performed on January 16, 1954. Five years after operation (February 17, 1960) the femoral head remains in position and if anything it seems to have moved downward and inward. The shelf shows no absorption whatever because it is in contact with the femoral head and neck throughout its full extent and therefore all parts of it are functional. The epiphysis, although flattened, has developed well and the femoral neck has elongated. The result in this hip resembles that seen in adults after the shelf procedure. The head and neck are held between two inclined planes, the shelf and the ilium. Above the head there is a fibrous abutment in the angle formed between the shelf and the ilium.

placed beneath the expansion of the rectus femoris and in contact with the capsule.

Convalescence and Recovery

Absorption of the shelf may cause decrease in the length, thickness, and width of the shelf. The decrease in length observed was the result of both true shortening and apparent shortening. With apparent shortening the shelf remained essentially the same length, but the pelvis and femoral head increased in size. In three hips there was apparent shortening but no true shortening of the shelf (Fig. 5); in the

remaining seventy-nine some actual, true shortening did occur. In fifty-eight the shortening was slight or insufficient to cause loss of support by the shelf (Fig. 4). Usually, shelves longer than need be were inserted at operation to provide for the expected shortening. The shortening in length was 25 per cent or less in six; 25 to 50 per cent in twenty-seven; 50 to 75 per cent in twenty-five; and over 75 per cent in twenty-one.

Loss of length of the graft, we believe, was the result of several factors. Little absorption took place when the outer portion of the shelf was functioning or under stress. Contact of the soft tissues with the shelf will always cause some absorption of the bone graft. Lack of good contact of the graft with the ilium or displacement of the periosteum raised from the ilium may also be factors. No increased tendency to absorption was observed in the healed, previously infected hips, even though considerable fibrosis was observed in the area of implant in these hips (Fig. 6).

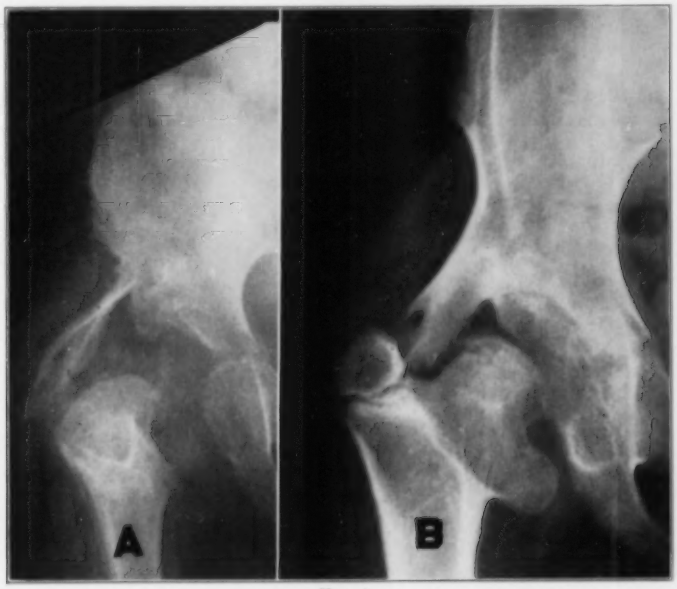

FIG. 6

November 5, 1953 February 17, 1960

Old suppurative arthritis and resultant unstable hip in a child two and one-half years old. Shelf operation was performed on September 23, 1953. Six years after operation the hip joint has a peculiar outline but it is stable and has excellent function. Note the apparent partial reformation of the capital femoral epiphysis; the seemingly more normal relationship of the femoral head to the acetabulum; and the apparent widening of the lower ilium and narrowing of the superior ilium. Although this shelf was implanted above the rim of the acetabulum, it has not moved upward with growth of the pelvis during the six years since operation (February 17, 1960).

The amount of loss of width of the graft due to absorption was impossible to determine but we believe that the loss of width is comparable to the loss in length, even though no actual measurements were possible.

Decrease in thickness of the shelf due to absorption usually paralleled loss in length. However, some shelves were observed to shorten without loss of thickness. In some cases the shelves grew thicker throughout their whole extent in the presence of some loss of length. Many of the shelves appeared to develop marrow cavities. In one patient with cerebral spastic paralysis five years after implantation of the shelf, a second operation was performed for the resection of the head and neck of the femur in order to facilitate nursing, correct deformity, and relieve pain after failure of the shelf operation. When the shelf was removed it was found to contain a marrow cavity (Fig. 7).

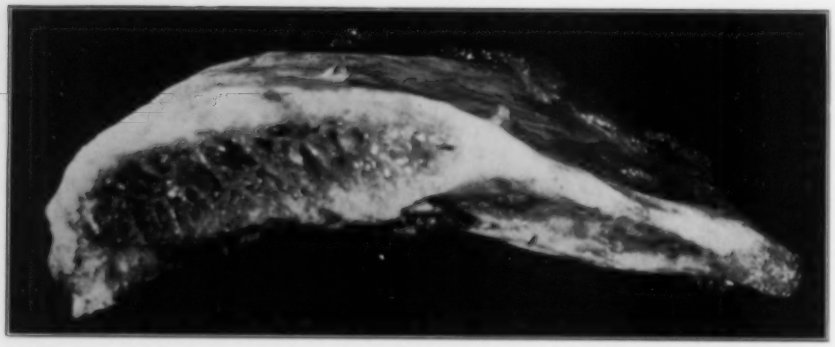

FIG. 7

Hip shelf removed five years after implantation. Note marrow cavity has formed within the graft. In this patient with spastic paralysis, resection of the head and neck of the femur was performed because the head of the femur dislocated posterior to the shelf and the resultant deformity complicated nursing care.

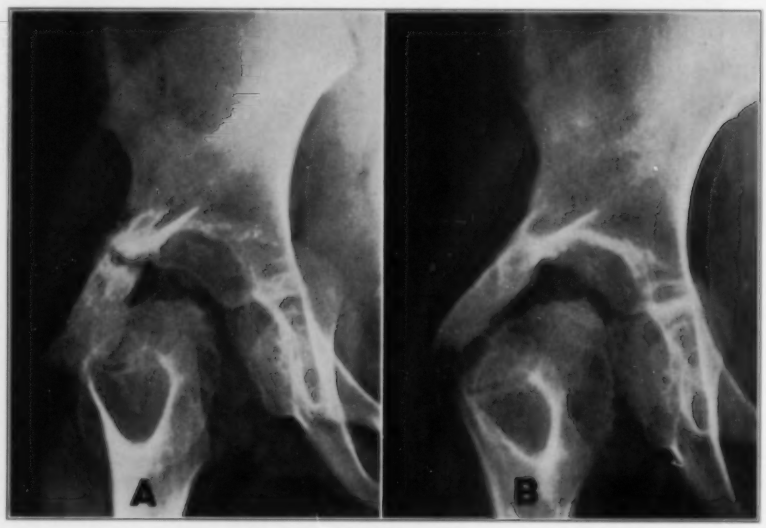

FIG. 8

January 30, 1950 July 14, 1950

Congenital dislocation of the hip with residual epiphysitis of the femoral head after repeated attempts at reduction. Shelf operation was performed on September 28, 1949, when the child was five and one-half years old. Fracture of the graft occurred on January 30, 1950, and healed without displacement of the graft. No follow-up evaluation or roentgenograms have been obtainable because of marital and legal difficulties.

Non-union between the shelf and the ilium occurred twice in this series. Seven of the shelves fractured (Fig. 8) but six of these reunited, providing good support without gross displacement. In the remaining patient, the shelf in its central portion absorbed after it had been fractured. Despite this, a satisfactory acetabular margin formed from the proximal portion of the graft (Fig. 9).

In all three of the patients with cerebral palsy whose dislocated hips were reduced and on whom shelf operations were performed, the hips redislocated and more severe deformities developed. In one patient, as already noted, it was necessary to resect the head and the neck of the femur. New-bone formation in the region of this patient's resected hip has occurred and a third operation to resect this bone may be necessary.

FIG. 9

September 28, 1954 March 18, 1955 February 29, 1960

Congenital dislocation of the hip in a child four years old. An open reduction was unsuccessful, and six months later a shelf was implanted (January 14, 1955). Even though the tenuous medial portion of the graft absorbed, the acetabulum deepened and the hip became stable. Either growth of the acetabular margin was stimulated by the insertion of the graft or there was some bone growth along the base of the shelf. Note the widening of the lower ilium and the narrowing of the upper ilium which gave an appearance similar to that seen after supra-acetabular osteotomy. Note also the more normal development of the femoral neck after implantation of the shelf.

FIG. 10

January 5, 1953 March 2, 1953 February 5, 1960

Congenital dislocation of the hip in a child four and one-half years old with epiphysitis of the femoral head following multiple unsuccessful manipulative reductions. The shelf was implanted on February 2, 1953. Seven years after operation (February 5, 1960) the functional portion of the shelf remains, the femoral neck has reformed to a considerable extent, the lower ilium has formed a wide buttress, and the upper ilium has become somewhat narrower. Note that even in the post-operative roentgenogram (March 2, 1953) the femoral head appears to have been replaced within the acetabulum to some extent as the result of the shelf.

LATE ROENTGENOGRAPHIC CHANGES

In seven hips osteochondrosis of the femoral head was present before operation, and this process continued after the shelf operation (Fig. 10). In one patient coxa vara developed in association with some absorption of the upper portion of

FIG. 11-A
December 6, 1951

FIG. 11-B
October 22, 1952

the femoral head. This process was present before implantation of the shelf and continued to progress thereafter.

In one patient with congenital dislocation of the hip and pre-existing severe osteochondrosis of the femoral head there developed progressive incongruity of the articular surfaces with flexion deformity of the hip, limited motion, and pain. Five years after the shelf operation, arthrodesis was done.

In none of the cases studied was there any indication that the femoral head was molded by the shelf. The contour of the head neither improved nor became worse after placement of the shelf.

In sixty of the hips studied no changes were observed at follow-up in the outline, location, or inclination of the roof of the acetabulum. In one hip the acetabulum became shallower and more inclined, whereas in the remaining

Fig. 11-C

January 12, 1960

Figs. 11-A, 11-B, and 11-C: Bilateral paralytic subluxation of the hip in a child six and one-half years of age with a myelomeningocele. Bilateral shelf operation was performed on April 2, 1952. The massive shelves maintained the femoral heads in position for approximately five years, then both hips gradually dislocated (January 12, 1960) and weight-bearing was discontinued.

twenty-two hips the acetabulum appeared to become deeper and the head better contained therein. Widening of the lower portion of the ilium, of the iliac portion of the acetabular margin, or of both of these portions of the ilium, probably accounted for this.

Marked changes of profound importance were observed in the ilium of all of the patients. The superior portion of the ilium usually became narrower, whereas the lower part above the acetabulum showed extensive widening. As a result, the appearance of the ilium and hip joint after the shelf procedure often resembled that seen following supra-acetabular pelvic osteotomy. A good part of the benefit of the shelf operation appears to result from this widening of the supra-acetabular portion of the ilium which follows the implantation of the shelf.

Both increases and decreases in the density of the bone in the graft and in the ilium were observed in the roentgenograms at the point of attachment of the shelf to the ilium. Whether these roentgenographic changes represented actual alterations in the bone structure at this point was not determined.

FUNCTIONAL RESULTS

No redislocations occurred following shelf application, except in the three patients with cerebral palsy and in one of the two patients with myelomeningocele (Fig. 11). At the present time all of the patients with paralytic dislocation of the hip due to poliomyelitis have done well. Their hips have remained stable at the same level as when the shelves were applied. In one of the patients with poliomyelitis, four years after operation, at the age of ten years, the femoral head is stable beneath the shelf during walking, standing, and manipulation of the joint with the hip in extension. Furthermore, the femoral head remains in place even when the patient is seated and during active motion of the hip. However, the hip can be subluxated backward passively when the thigh is flexed to 90 degrees. Although this instability causes no symptoms we plan to add a posterior lip to this shelf.

FIG. 12

September 26, 1955 November 21, 1957 October 30, 1958 March 31, 1959

Bilateral dislocation of the hip developing at two years of age in a child with severe spastic tetraplegia. Shelf operations were performed on October 27, 1958, at four years of age. During the next two years the dislocation gradually recurred although the shelves seemed to remain intact. Because of the dislocation and resultant deformities, nursing care is difficult and the patient's ability to sit or be recumbent is impaired. Further surgery is contemplated. This case, a failure with a follow-up of less than two years, is not included in this series.

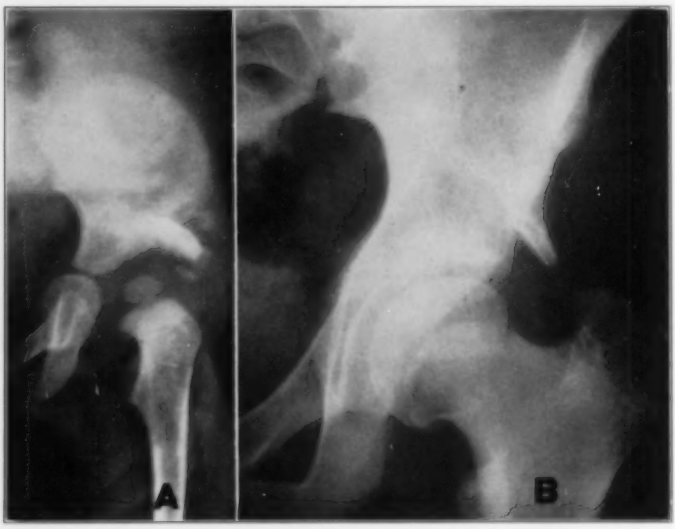

FIG. 13

December 19, 1949 February 24, 1960

Congenital dislocation of the hip unreduced at one and a half years of age. Shelf procedure performed at that time, November 22, 1949. Because of subluxation of the femoral head, the implant was placed slightly high. Initially, the shelf appeared to be functional. Stimulation of the superior margin of the acetabulum appears to have occurred. The socket grew deeper, with the head centrally placed and stable within the acetabulum. As the acetabulum developed the shelf was no longer functional and absorption occurred. Ten years after operation the femoral head and neck have developed well, the roof of the acetabulum is of nearly normal slope and width, and the remnant of the non-functional shelf can be seen above the acetabulum. No casts or any form of abduction apparatus was used; the legs were merely bandaged together for a short period after implantation of the shelf.

FIG. 14

October 27, 1937 February 7, 1959

Congenital dislocation of the hip still unreduced at fourteen years of age, October 27, 1937. Shelf operation performed at this time (December 23, 1937). Twenty-two years later the hip is stable and the patient has an excellent clinical result (February 7, 1959). Other procedures, such as a Colonna reconstruction, a high femoral osteotomy, or hip fusion, might well have been considered.

No adverse effects of the shelf on hip function have been observed. There was no significant loss of motion because of bone block or adhesions, no increased muscle weakness, and no increase in instability.

It was impossible to evaluate the functional results of these operations quantitatively. If the Trendelenburg test was positive before operation, it remained so afterward. Despite this, the gait was improved, since the greater stability of the hip after the shelf operation enabled the child to swing the weight of the trunk onto the femoral head during the stance phase without fear of or actual loss of support due to telescoping of the hip. In certain instances, where actual subluxation and reduction of the femoral head could be demonstrated by manipulation and no active abduction was possible before the shelf operation, active abduction was definitely restored, although in variable amounts. The gait of the patients with a good shelf improved markedly, much more than would have been anticipated in view of the persistently positive Trendelenburg test and the muscle weakness. To see a child who lurched badly and tired quickly because of a weak, unstable hip before operation be able to walk and play all day with the other children—without lurch or fatigue, although still with a limp—is convincing evidence of the value of this procedure.

DISCUSSION

The results following the shelf operation depend on: (1) the age of the patient; (2) the disease causing the hip disability; (3) the type of hip disability; and (4) the adequacy of the operation in terms of the location, size, and security of the implantation of the shelf.

Age has been thought to have a significant effect on the results after shelf

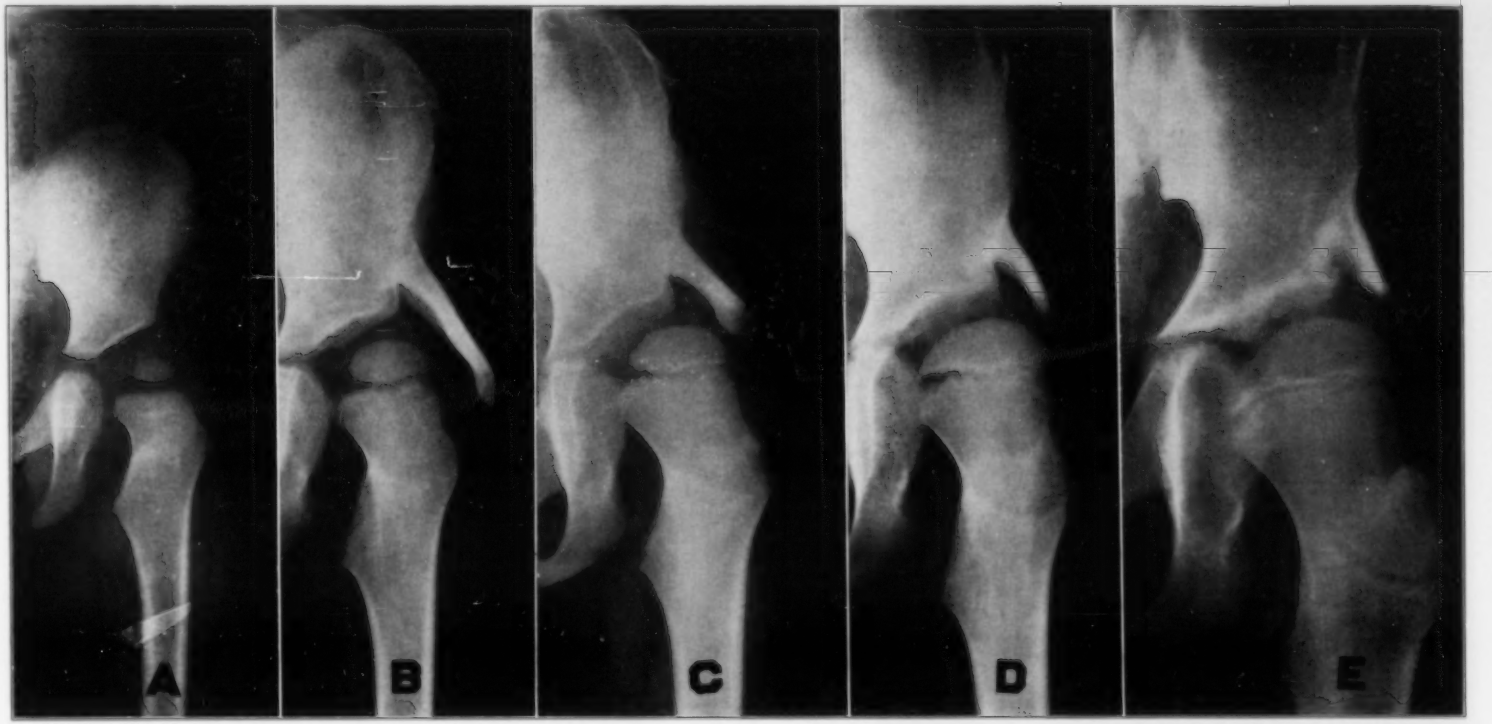

FIG. 15

May 21, 1950 | March 26, 1953 | March 24, 1954 | April 11, 1956 | December 15, 1959

Paralytic dislocation of the hip due to anterior poliomyelitis in a child, four years old. Before operation (May 21, 1950), the hip could be dislocated and reduced manually. A shelf operation performed on November 19, 1952, made the hip stable. The superior margin of the acetabulum thereafter became wider and the socket grew somewhat deeper. The peripheral, non-functional part of the shelf has gradually absorbed during the seven years since (December 15, 1959). Notwithstanding, the hip in this flail extremity has remained stable.

FIG. 16

July 5, 1949 October 21, 1949 February 12, 1960

Old suppurative arthritis of the hip in a child seven years old (July 5, 1949). A shelf procedure was performed on July 20, 1949. The shelf has remained functional and has hypertrophied in the ten years since operation (February 12, 1960). Despite the flattening and varus deformity of the remnant of the femoral head and neck, both of which favor lateral displacement, this hip joint has remained stable and considerable deepening of the socket has occurred. The shelf appears to have provided an inclined abutment, preventing lateral displacement of the hip, despite the obliquity of the socket.

operation. With growth and remodeling of the pelvis it was anticipated that the shelves would absorb or tend to move away from the acetabulum to a higher level, resulting in inadequate support for the femoral head. In this series no properly placed shelf showed any tendency to move to a higher location as the result of growth. The changes in the shelves have occurred with equal frequency in both the older and the younger age groups.

The disease responsible for the disability of the hip has shown no correlation with the results after shelf operation, with the exception of cerebral palsy. All three shelf operations on the patients with cerebral palsy were failures. The procedure appears to be valueless for dislocations or subluxations of the hip associated with this disease.

The nature of the hip disability (dislocation, subluxation, aplasia of the acetabulum, absorption of a previously applied shelf, or coxa magna) had no influence on the results in this series.

Since these factors do not appear to influence the results, what is responsible for the considerable variation in the late results observed after the shelf operation?

It has become clear to us that the die is cast, and the final result forecast at the time of operation. If a shelf of adequate size has been implanted in a properly located slot at the attachment of the capsule of the hip joint with the distal end of the graft fixed beneath the reflected head of the rectus femoris tendon, the results have been good routinely, except in the patients with cerebral palsy. Although other factors may influence the result, a thorough review of the patients in this series and their roentgenograms indicates that in the main the operative technique is the essential factor determining the results.

To expand the reader's concepts and provide a greater amount of material for visual review and study, we add hereto five specific cases, each with a different diagnosis, each representing a different problem:

1. A cerebral palsy patient with marked spasm, redislocation after shelf ap-

plication, who eventually may need resection of the head and neck of the femur for comfort (Fig. 12);

2. An infant, aged one and one-half years, who had an unstable congenital subluxating hip, still stabilized by a shelf nine years later (Fig. 13);

3. A totally dislocated congenital hip stabilized by a satisfactory shelf (Fig. 14);

4. A postpoliomyelitis subluxating hip, in which the head of the femur could be manually dislocated and replaced in the socket, stabilized by shelf application (Fig. 15);

5. A partially destroyed and unstable hip, residual of suppurative arthritis, stabilized by shelf application (Fig. 16).

CONCLUSIONS

1. The main factor that determines a satisfactory result is the operative technique;

2. The shelf operation for dislocated hips in spastic paralysis is without value;

3. The age of the patient appears to have little influence on the result;

4. Changes in the ilium induced by shelf implantation appear to be extremely important;

5. When the local condition indicates the need to stabilize a hip in a child, a shelf can be an invaluable asset.

Radioactive Sulphur in Chondrosarcomata

The Distribution, Concentration, and Effects of S^{35} after Intravenous Administration to Patients with Chondrosarcoma *†

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Total eradication of a localized tumor is still the only method for permanent cure of cancer. Once a tumor has become too widespread to be amenable to surgery or radiotherapy, the hope of controlling it rests on the availability of an agent that is able, after systemic administration, to inhibit or destroy the malignant cells in any location because of some peculiarity of the tumor metabolism.

Some tumors share with their tissue of origin a high requirement for a specific metabolite. Its utilization may be greater than in the normal tissue because of the increased metabolism of tumors, or lower because of lesser differentiation. The product for which the tumor has a high affinity can be made toxic by replacing a normal atom by its radioactive isotope, or the cells can be injured by a related unnatural chemical compound (antimetabolite). The systemic administration of isotopes or of chemotherapeutic agents has to its credit many cases of temporary regression of tumors and of increased survival times, although permanent cures have probably never been obtained.

The investigations reported in this paper were based on the demonstration by Dziewiatkowski and associates[3] that radioactive sulphur administered as sulphate was selectively concentrated by cartilage. This paper reports studies on the localization and concentration of tracer amounts of radioactive sulphur (S^{35}) in five patients with chondrosarcomata and a therapeutic trial of large amounts of S^{35} in three patients with advanced chondrosarcomata.

Localization and Concentration of S^{35} in Chondrosarcomata and Other Tissues

Introduction

Initial tracer studies on two patients demonstrated that S^{35} was selectively fixed in human cartilage and chondrosarcomata[6]. These studies were extended to ascertain the degree of uptake of S^{35} in chondrosarcomata and in other tissues at varied intervals after injection.

Methods

Radioactive sulphur was administered as a solution of sodium sulphate ($Na_2S^{35}O_4$) in neutral physiological saline through the tubing of an intravenous-drip apparatus delivering 5 per cent glucose in water. The distribution of the isotope could be studied only on specimens obtained at surgery or autopsy, since the weak beta radiation of S^{35} is completely arrested by the skin. The tissues were used for chemical analysis, autoradiographs, and surface counting.

Most samples were analyzed for total isotopic sulphur by oxidation with

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† This investigation was supported in part by Grant C-2770 of the National Cancer Institute and by a grant of the Alexander and Margaret Stewart Trust Fund.

Denis's reagent as previously described [6,13]. The tissues of Patients B and C were oxidized with nitric and perchloric acid by a modification of the method of Evans and St. John, and the barium-sulphate precipitate was counted *. For normal tissues the analyses on duplicate samples agreed closely. The results were more variable for tissues of mixed composition, such as inflammatory tissues, tumors, and cancellous bone. The nature of the tissues analyzed was verified by microscopic examination of adjacent samples.

The surface radioactivity of excised tissues was measured by placing a thin-windowed Geiger-Mueller tube, one inch or one-quarter of an inch in diameter, against flat areas of the surgical specimens. The smaller tube, developed to measure the uptake of P^{32} in the eye [21], can be sterilized and immersed in liquid.

Autoradiographs were made with Kodak Contrast Ortho Process film [13]. Initially, they were prepared in duplicate, one with the film in direct contact with the tissue section, the other with the film held at a short distance by cellophane strips to exclude the production of pseudophotographic effects. Kodak liquid emulsion NTB 2 was also used for tissues obtained after injection of large amounts of S^{35}.

CASES STUDIED

Tracer amounts of S^{35} (1.8 to 6.7 millicuries) were administered to patients having chondrosarcoma or sarcoma prior to tumor biopsy or resection.

PATIENT C **, a white man, thirty-one years old, sustained, in June 1952, a pathological fracture through a cystic radiolucent area of the intertrochanteric part of the femur. The tumor was thought to be benign and was curetted. The defect was packed with bank bone, and the fracture was immobilized with a nail and plate. Microscopic examination of the tissue removed from the lesion showed a moderately well differentiated endosteal chondrosarcoma. Ten days after this operation, a tracer dose of S^{35} was given, and a hemipelvectomy was carried out twenty-two hours later. No residual focus of chondrosarcoma could be found. The localization of S^{35} was studied in the normal and repairing tissues. Four years later metastases were excised from the skin, the left lung and mediastinal lymph nodes, and from the pectoralis major muscle. The tumors were poorly differentiated, resembling fibrosarcomata. Bone metastases subsequently appeared, and the patient died in April 1957.

PATIENT B †, a white man, forty-six years old, had multiple exostoses (diaphyseal aclasis). In July 1952 he had a bulky peripheral chondrosarcoma of the femur that had appeared about two years previously in the area of the lesser trochanter. Hemipelvectomy was performed twenty-six hours after injection of S^{35}. The tumor was well differentiated with cartilage-like nodules and calcified areas; in the center it was myxoid and cystic. Several exostoses with cartilaginous caps were found on the ilium, femur, and fibula. The knee joint contained two intra-articular loose bodies. An exostosis of the scapula was resected in October 1952. The patient was in good health in January 1960.

PATIENT W ‡, a Negro boy, seventeen years old, in July 1955 underwent a block dissection of a generally poorly differentiated chondrosarcoma of the ilium adjacent to the sacro-iliac joint. There had been symptoms for about five months. The tumor recurred locally and produced fecal impaction. In November 1955, forty-eight hours after injection of S^{35}, biopsies were obtained from the tumor and from a rib. The patient died in February 1956; there was direct tumor invasion of the femoral and external iliac veins and of the inferior vena cava. There were also tumor emboli in the pulmonary arteries and metastases to the liver.

* The perchloric-acid method gave complete oxidation of cystine, but only partial oxidation of methionine. The recovery of $Na_2S^{35}O_4$ was 91 to 104 per cent. For routine use, Denis's method is more convenient but is also lengthy. Results suitable for clinical use can be obtained by wet ashing with nitric acid, or by hydrochloric-acid hydrolysis (see reference 4), since there is little conversion in the body of S^{35}-sulphate into amino-acid sulphur [3].

** Courtesy of Dr. M. N. Donovan and Dr. F. F. Parrish, Houston, Texas.

† Courtesy of Dr. M. N. Donovan and Dr. F. F. Parrish, Houston, Texas.

‡ Courtesy of Dr. H. L. Feffer and Dr. J. P. Adams, Washington, D. C.

PATIENT G §, a Negro man, forty-one years old, had a tumor of the head of the tibia that had appeared in 1946. A biopsy in 1948 was reported, probably erroneously, as enchondroma, and the tumor was curetted several times. In November 1951, the microscopic examination showed a generally well differentiated chondrosarcoma with chondroid and myxoid areas. Radioactive sulphur was administered, and a mid-thigh amputation was performed fifty hours later. A metastatic nodule was present in the subcutaneous tissue. In September 1954, a lymph node with metastatic chondrosarcoma was excised from the left forearm. The patient died in October 1954; there were widespread tumors. No autopsy was performed.

PATIENT H ‖, a Negro man, twenty-six years old, had a poorly differentiated chondrosarcoma of the iliac wing invading the sacrum and the soft tissues of the pelvis. The first symptoms had developed in April 1951. The tumor was incompletely resected by hemipelvectomy in September 1951. In November 1951, biopsies were taken sixty-five hours after administration of S^{35}. At this time there were pulmonary metastases, serosanguineous fluid in the left pleural cavity, and a reduced urinary output. Signs of obstruction of the superior vena cava developed, and the patient died eleven days after the tracer injection. There were metastases in the liver, lymph nodes, lungs and pleurae, and tumor invasion of the pulmonary arteries.

PATIENT M #, a Negro man, forty-seven years old, had a pleomorphic sarcoma arising in the biceps femoris muscle. The tumor was very cellular with elongated cells and many bizarre and multinucleated cells. Only very few areas showed formation of ground substance or of osteoid or chondroid matrix. The first symptoms appeared in January 1958. The wound of the biopsy site did not heal. A block dissection was carried out in April 1958, sixty-five hours after injection of S^{35}. In July 1958, the extremity was disarticulated at the hip because of tumor recurrence with metastases to a lymph node and bone. The patient died in January 1959; there were tumor extension to the psoas area, metastases to the lungs, left pleura, and brain, and recent pulmonary embolism.

Results

Table I gives the concentrations of S^{35} observed in various tissues at increasing intervals after injection of the isotope. The concentrations of isotope retained per gram of tissue are expressed as per cent of the amount of isotope administered per gram of body weight.

The analyses showed the generally high uptake of the isotope in cartilage and in chondrosarcomata. The average concentrations of isotope in the chondrosarcomata varied from 62 to 440 per cent of the concentrations found in normal cartilage. Uptakes higher than average were found in the growing portions of the tumors. The fixation of S^{35} seemed to result from both the formation of cartilaginous ground substance and the increased metabolism of neoplastic cells. The pleomorphic sarcoma of Patient M, almost devoid of ground substance, contained less S^{35} than the chondrosarcomata studied after similar intervals. Anaplastic fibrosarcomatous metastases of chondrosarcoma also retain less S^{35} than metastases with cartilaginous or myxoid differentiation [14].

In Patient B, the benign chondromata, either exostoses or intra-articular loose bodies, had somewhat lower and less variable uptakes of S^{35} than the chondrosarcoma did.

A high uptake of radioactive sulphur also occurs in newly formed connective tissue and bone, since their ground substances contain sulphated mucopolysaccharides. The amounts of radioactive sulphur found in the healing wounds and in the repairing bone of Patient C were much larger than those found in resting connective tissue or bone. The inflamed fibrous membrane left around the tumor cavity after curettement also retained important amounts of the isotope.

The high uptake of S^{35} in repairing and inflamed mesenchymatous structures was also noted in Patient M. The granulation tissue of the skin wound of the previous biopsy site had a 93.1 per cent uptake. Autoradiographs showed that

§ Tissue analyses on this patient were reported previously [6].
‖ Tissue analyses on this patient were reported previously [6].
Courtesy of Dr. J. P. Adams, Washington, D.C.

TABLE I

CONCENTRATION OF RADIOACTIVE SULPHUR PER GRAM OF TISSUE AFTER INTRAVENOUS INJECTION OF TRACER AMOUNTS EXPRESSED AS PERCENTAGE OF THE AMOUNT OF ISOTOPE ADMINISTERED PER GRAM OF BODY WEIGHT

Patient:	C	B	W	G	H	M	H	W
Time lapse between injection and operation:	22 hours	26 hours	48 hours	50 hours	65 hours	65 hours	11 days	73 days
Amount of S^{35} injected (millicuries):	2.2	5.1	5.9	2.9	6.7	1.8	Autopsy	Autopsy
Body weight (kilograms):	70	87	57	55	54	82		
Concentration of S^{35} in tissues (percentage of injected amount)								
Skin (epidermis and dermis):	46.2	46.3	10.0	25.6	26.5	25.6	6.7	
Subcutaneous adipose tissue:	19.6	14.6		6.8	13.8	3.6	1.5	
Muscle:	10.4	6.8	3.1	3.2		3.2	0.7	
Chondrosarcoma								
Average:	(97.1[a])*†	74.7	50.3	197.0	84.0	(23.2[n])*	95.7[r]	3.2
Maximum:		168.3	72.0[g]	251.4	103.5	(40.1[o])	168.6	8.2[r]
Minimum:		25.2	39.5[k]	130.8	64.5	(8.6[p])	24.7	0.3[k]
Number of samples:	(1)	(9)	(6)	(4)	(2)	(4)	(6)	(11)
Chondroma								
Average:		58.4[b]						
Maximum:		84.4						
Minimum:		35.2						
Number of samples:		6						
Cartilage:	58.6[b]	88.6[b]	80.8[t]	44.6[b]			58.5[s]	
Cortical bone:	4.5[e]	3.6[e]	28.2[t]	11.5[e]			2.5[s]	
Adipose marrow:	2.1	3.1						
Red marrow:	117.5[d]	128.0[d]	90.7[t]	(8.4[m])			33.1[u]	
Nerve:	19.3	36.4						
Fibrous tissue:	25.5[o]					34.6[o]		
Inflammatory tissue:	89.5[f]					93.1[f]		
Repairing bone:	115.2[g]	25.6[g]						
Blood:	26.0	9.7		7.3	7.4	1.8	1.0	
Serum:	31.5		7.4			2.9		

* Parentheses are used when samples differ from the corresponding headings. In Patient C, only inflammatory tissue was obtained, and in Patient M, the tumor was an anaplastic sarcoma.

† a = inflamed fibrous membrane of curetted area; b = articular cartilage; c = diaphysis of tibia or femur; d = red marrow with cancellous bone of ilium; e = tendon; f = healing surgical wound in soft tissues; g = repairing bone and fibrous tissue near fracture site; h = cartilaginous joint body, and cartilaginous and bone cortex of two osteochondromata—the red marrow inside an exostosis had an 88.1 per cent uptake; i = eburnated cortex of femur beneath the chondrosarcoma; j = tumor capsule; k = deep, poorly differentiated tumor; l = rib; m = aspirated bone marrow, ten days after S^{35} injection; n = pleomorphic sarcoma; o = fibrosarcomatous area with some osteoid spicules; p = anaplastic giant-cell area; q = inflamed arterial wall; r = local chondrosarcoma and lung metastasis; s = rib and trachea; t = skull; u = cancellous bone of sternum; and v = cartilage-like nodule deep in the tumor.

the regenerating acanthotic epidermis did not share the high uptake of the subjacent granulation tissue (Figs. 1-A and 1-B). At the periphery of the sarcoma, inflamed muscle had a 24.7 per cent uptake, and waxy atrophic muscle with marked fibrosis had a 19.5 per cent uptake, whereas the uninvolved voluntary muscle had the usual low uptake (3.2 per cent).

Early after injection the hematopoietic bone marrow contained more S^{35} than did the cartilage, but this uptake appeared relatively short-lived, whereas the rate of disappearance of S^{35} from cartilaginous tissue was very slow. Most other tissues had a rapid turnover. This is illustrated in Chart I, which combines data from the different patients. When Patient W died seventy-three days after injection, significant amounts of S^{35} were still found in his tumor despite the lowest initial uptake in his chondrosarcoma (Table I).

Table II lists the surface counts measured over excised specimens and the isotope content of these samples determined by chemical analysis. A large Geiger-Mueller tube was needed to record a sufficient number of counts after tracer injection, whereas a smaller tube could be used after injection of large amounts (Patient 2).

TABLE II

SURFACE COUNTS AND S^{35} CONTENT OF TISSUES OBTAINED AT OPERATION

	Patient B: 3.1 Millicuries of S^{35} *				Patient 2: 926 Millicuries of S^{35}‡			
		S^{35} by Analysis		Surface Counts		S^{35} by Analysis		Surface Counts
Tissue	Sample Number	Percentage Concentration	Microcuries per Gram	Net Counts per Minute	Sample Number	Percentage Concentration	Microcuries per Gram	Net Counts per Minute
Skin		46.3 (40.8;51.8)†	0.027	138 (134;143)		9.4 (8.9;9.9)	0.801	116§ 209¶
Subcutaneous adipose tissue		14.6 (12.3;16.9)	0.008	21 (20 to 22)		0.61 (0.54;0.68)	0.052	21
Muscle		6.8 (6.2;7.3)	0.004	16 (13;19)		0.49 (0.49;0.49)	0.042	22
Fascia						31.2 (28.3;34.1)	2.650	331
Chondrosarcoma	A. Cartilage-like superficial tumor	140.1 (112;168.3)	0.081	142 (97 to 211)	A. Nodular cartilaginous tumor with stroma, hard	115.5 (90.6;140.4)	9.790	639
	B. Deeper yellow cartilaginous tumor	55.1 (33.5;76.8)	0.032	65	B. Nodular cartilaginous tumor, with more stroma, soft	51.6 (49.8;53.3)	4.380	305
	C. Central semi-liquid tumor	28.8 (25.2 to 32.6)	0.017		C. Calcified tumors	22.3 (13.6;30.9)	1.890	315
					D. Superficial cartilaginous tumor, white	189.9 (189.6;190.1)	16.100	3317 (3118; 3517)
					E. Deep cartilaginous tumor, white-yellow	79.3 (20.7;137.8)	6.720	1227
					F. Deep tumor stroma, soft, yellow	15.3 (14.3;16.3)	1.300	329
Blood		9.7 (9.4;10.0)	0.006			0.25 (0.25;0.25)	0.021	7

* Twenty-six hours after injection; surface counts were made over large areas with a Tracerlab tube (1.0-inch diameter, 1.8 milligram per square centimeter, 1,200 volts) and interposed plastic.
† The figures in parentheses give the values or the range of the individual determinations.
‡ Sixteen days after last injection; surface counts on small specimens made with an Anton miniature tube 222, one-fourth-inch diameter, 1.4 milligrams per square centimeter, 750 volts.
§ Epidermis side.
¶ Dermis side.

The surface radioactivity values had a positive correlation with the S^{35} content of the tissues, but they were not strictly proportional since the surface counts were dependent only on the structure of the most superficial layer (maximum range of the radiation in tissues: 0.3 millimeter). Furthermore, even adjacent samples of tumor varied widely in isotope content (Table II).

The autoradiographs of tissues from the patients who received tracer doses * showed that the isotope was deposited near metabolically active cells of cartilage and of chondrosarcomata. The greatest uptake occurred in the areas of ground-substance formation (Fig. 2-B) and where the malignant cells were well preserved (Figs. 3-A and 3-B). Refined techniques demonstrated the deposition of the isotope in the ground substance surrounding the individual benign or malignant chondrocytes (Fig. 4). This resulted in maximum accumulation of S^{35} in the portions of the chondrosarcomata laying down ground substance at the time of

* Some of the observations on autoradiographs have been included in an abstract [7] and in an exhibit [8].

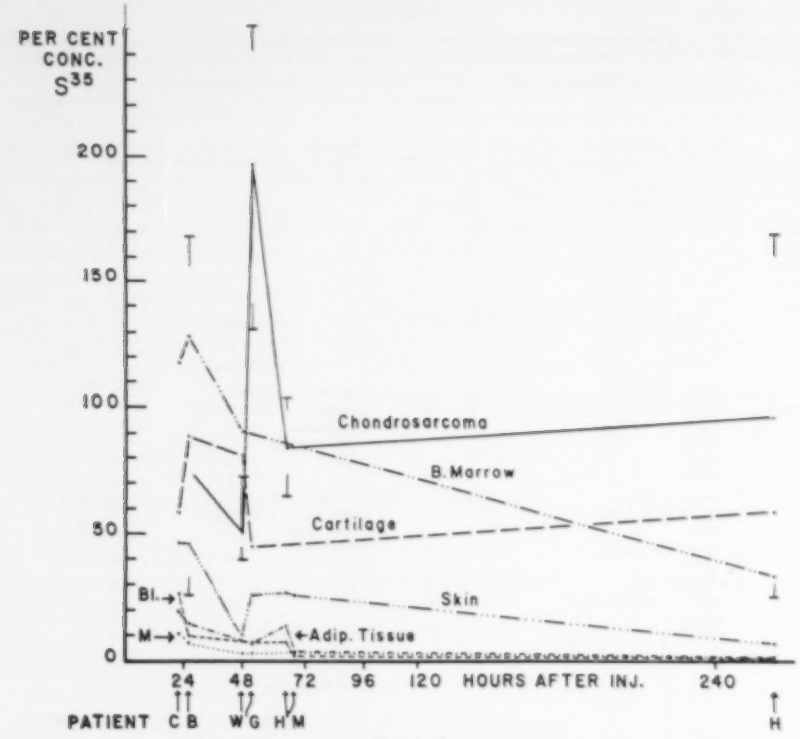

CHART I

Composite graph showing the relative concentrations of radiosulphur in the tissues of different patients at various intervals after injection of a tracer amount. *Bl* (- - -) indicates blood concentrations, *M* (. . .) indicates muscle concentrations. Solid lines join the average concentration values in the different chondrosarcomata, whereas the extremities of the corresponding vertical lines (⊤ and ⊥) indicate the maximum and minimum concentrations observed in each chondrosarcoma. The values of Patients G and M are slightly displaced along the time axis for better separation. There are no values given for the tumors of Patient C at twenty-two hours and for Patient M at sixty-five hours, since chondrosarcoma tissue was not available in these two instances. (See Table I.)

injection, generally at the growing margins (Fig. 3-B). Chondrosarcomatous metastases also fixed the isotope (Figs. 5-A and 5-B). Once deposited, the radiosulphur remained "embedded" for extensive periods of time. The portions of the chondrosarcoma that grew sometime after the injection of the tracer dose, when the blood level had become low, contained less isotope, so that a dynamic picture of the growth of the tumor was provided by the pattern of the autoradiographs in the same way that a dynamic picture of the growth of bones and teeth is provided by the retention of metallic salts in the "growth lines" (Figs. 6-A and 6-B).

Autoradiographs demonstrated that the S^{35} was fixed near well preserved chondrocytes in the chondromata (Figs. 7-A and 7-B). Some uptake also occurred in the bony parts of the osteochondromata.

Radioactive sulphur was deposited at the sites of proliferation of connective tissue in the capsule of tumors (Figs. 3-B and 6-B) and in inflammatory tissues (Figs. 1-B and 8-B).

Autoradiographs showed that normal cortical bone had a very low uptake, and that thin bone trabeculae had a slightly higher uptake. Larger amounts were demonstrated in newly formed bone (Figs. 8-A and 8-B) and in the callus of the healing fracture of Patient C.

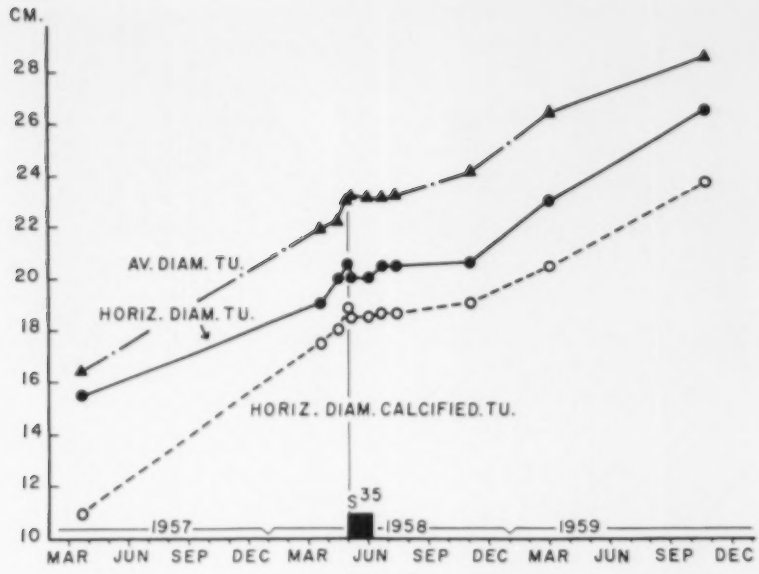

CHART II

Measurements on roentgenograms of the chondrosarcoma of Patient 2 (maximum horizontal diameter of the entire tumor, maximum horizontal diameter of calcified areas, and average diameter calculated from the surface of the anteroposterior projection of the tumor). (Reproduced from Gottschalk, R. G.; Alpert, L. K.; and Miller, P. O.: The Use of Large Amounts of Sulfur in Patients with Advanced Chondrosarcomas. I. Clinical and Hematologic Observations. Cancer Res., 19: 1070–1077, 1959. It also includes more recent measurements.)

Comment

The chemical analyses demonstrated grossly, and the autoradiographs demonstrated microscopically, the deposition of S^{35} in proliferating areas of mesen-

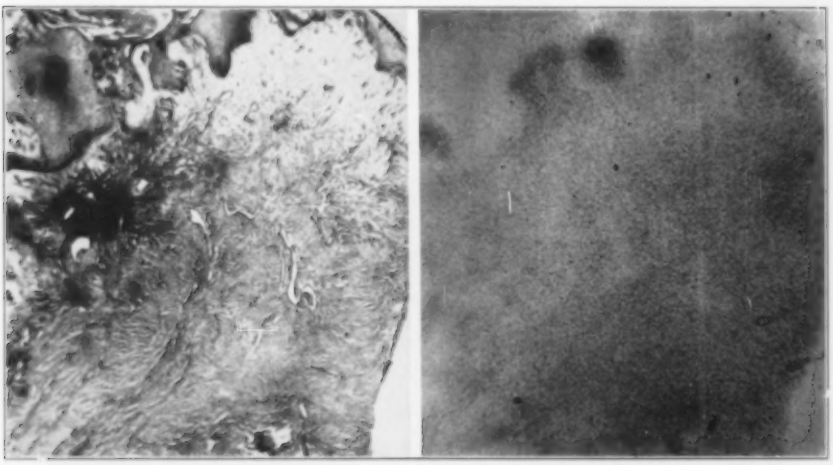

FIG. 1-A FIG. 1-B

Figs. 1-A and 1-B: Autoradiograph of section of the repairing skin wound of Patient M, sixty-five hours after S^{35} injection.

Fig. 1-A: Photomicrograph of thick microscopic section (thirty micra), stained with hematoxylin and eosin, reduced from × 22.

Fig. 1-B: Contact autoradiograph obtained from this section, ninety-four days' exposure, same magnification. S^{35} is retained in the deep areas of fibrosis and in the vascular granulation tissue underlying the hyperplastic epidermis, but not in the latter.

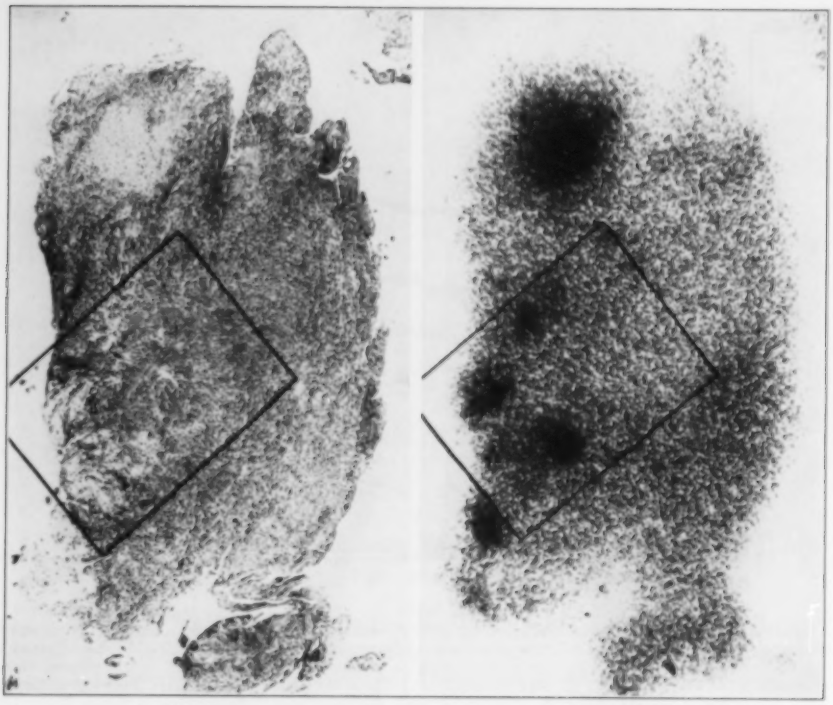

FIG. 2-A FIG. 2-B

Figs. 2-A through 2-C: Chondrosarcoma of Patient H; recurrence in the pelvis biopsied sixty-five hours after S^{35} injection.

Fig. 2-A: Five-micra section, stained with hematoxylin and eosin, reduced from × 53.

Fig. 2-B: Autoradiograph obtained from this section held at a distance of about twenty micra, ninety-seven days' exposure, same magnification. S^{35} is retained throughout the generally anaplastic tumor and to a greater degree in the well differentiated areas with more abundant ground substance.

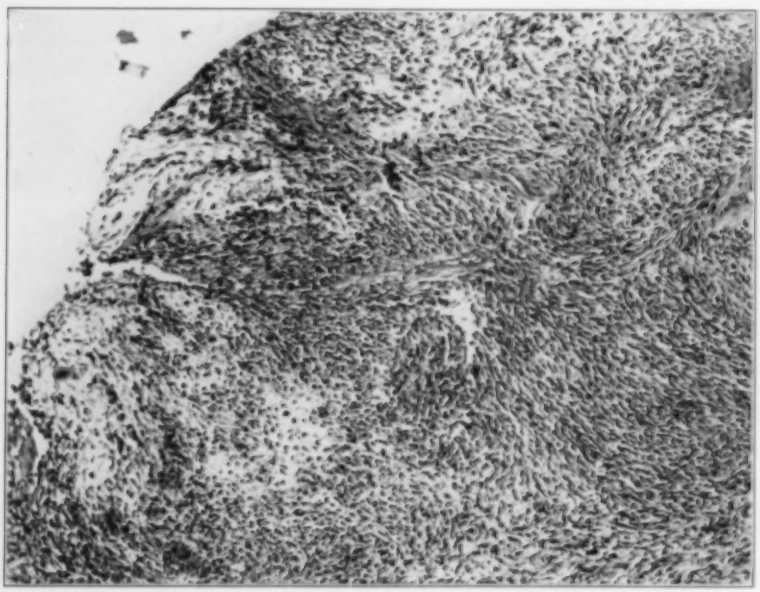

FIG. 2-C

Higher magnification (reduced from × 120) of the area outlined in Figs. 2-A and 2-B, showing chondrosarcomatous and anaplastic patterns.

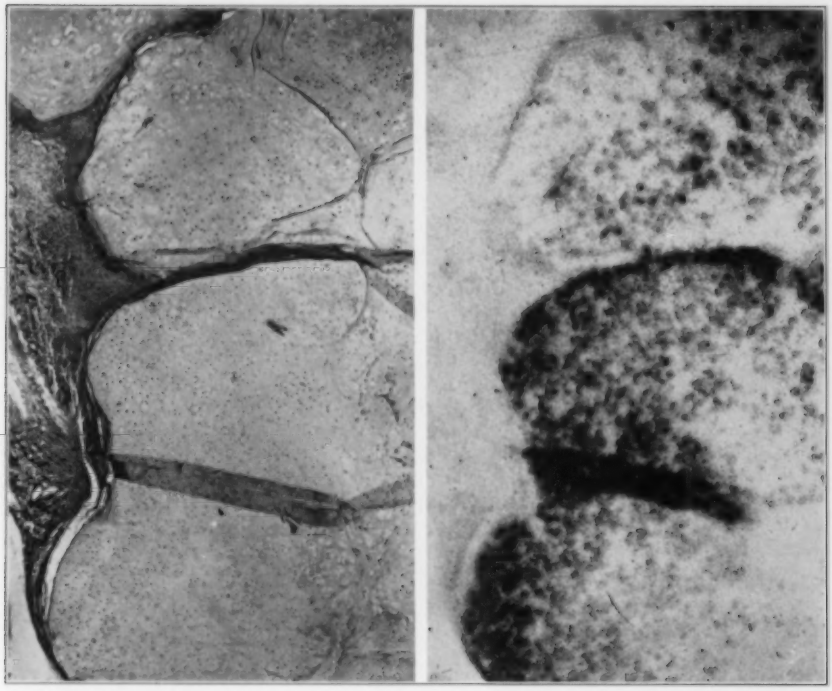

FIG. 3-A FIG. 3-B

Figs. 3-A and 3-B: Peripheral portion of chondrosarcoma of Patient B; amputation twenty-six hours after S^{35} injection.

Fig. 3-A: Six-micra section, hematoxylin and eosin, reduced from × 21.

Fig. 3-B: Contact autoradiograph, eighty-four days' exposure, same magnification. Folds in the microscopic section are reflected in the autoradiograph; they help to locate the corresponding areas. The tumor forms cartilaginous nodules surrounded by a fibrous capsule. Maximum uptake occurs in the chondrosarcoma in proliferating areas near individual cells with well preserved nuclei. The areas devoid of cells, with empty lacunae, or with pyknotic cells, fix little S^{35}. The newly formed connective tissue of the capsule has an appreciable uptake.

chymatous structures and, to a higher degree, in chondrosarcomata. This favorable pattern of distribution could be put to therapeutic use only if the injection of large amounts of S^{35} resulted in sufficient concentrations in the tissues to have biological effects. The beta radiation of radiosulphur has a low energy (average: 0.049 mev). The rapid urinary excretion of sulphate further increases the amounts of isotope required. Fortunately, S^{35}-sulphate is available as a carrier-free isotope, and the weight of the isotopic sulphur administered, even at the highest dosage, represented only a chemical trace compared with the amounts of sulphate normally found in the blood and tissues. In this regard, the situation is more favorable for S^{35} than it is with radioactive isotopes of elements found only in trace amounts in some tissues (like zinc in the prostate)[15], or with elements unnatural for the body, such as gallium[18].

When sufficiently large amounts of radioactive sulphate were injected into mice[10,11], the growing epiphyseal cartilage plates were selectively and permanently destroyed, whereas the bone marrow was only temporarily depressed. When still higher amounts of S^{35} were given, leukopenia developed, and the animals died with aplastic bone marrow, the typical picture of acute radiation injury. In young rats[9,10,20] sublethal doses of radioactive sulphur produced a permanent arrest of endochondral bone growth, and the animals developed into achondroplastic dwarfs. The destruction of the chondrocytes by the radioactive isotope

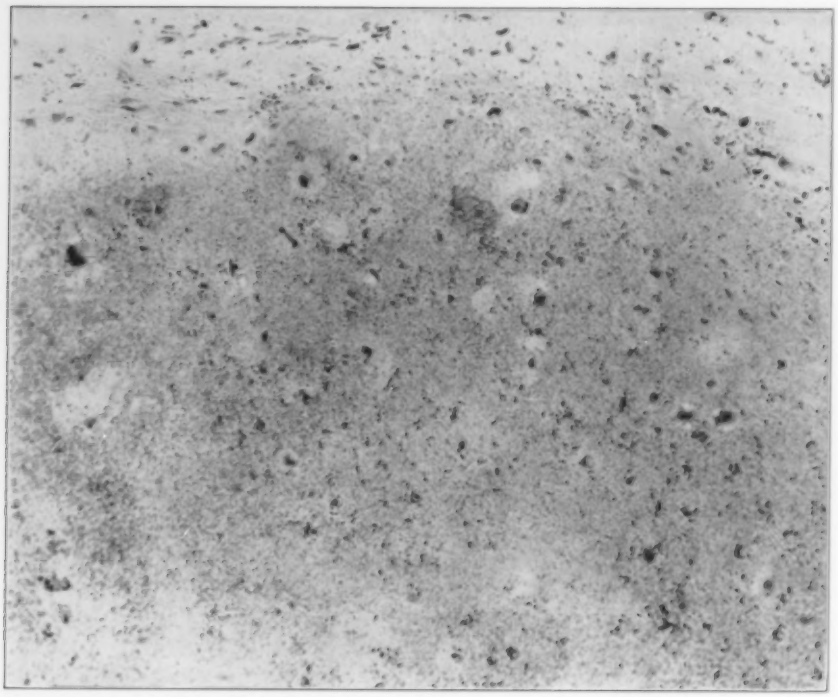

FIG. 4

Chondrosarcoma of Patient 2, sixteen days after the last of a series of large injections of S^{35}. The microscopic section (seven micra) was coated with liquid emulsion. After sixty-three days' exposure the emulsion was developed, and the section was stained with hematoxylin and eosin. The photomicrograph (reduced from 190) was focused on the silver grains, and the subjacent cells are slightly out of focus. Radioactivity is present in the ground substance, forming a halo around the malignant chondrocytes. Early after injection the S^{35} is closest to the chondrocytes; with continued growth of the tumor the S^{35} is displaced away from the cells. There is little radioactivity in the soft tissue around the chondrosarcoma (top).

deposited near them resulted in disorganization of the epiphyseal plates and in the arrest of endochondral ossification. These lesions were different from those produced by radioactive strontium, which is deposited in the newly formed bone trabeculae of the metaphyses [11,17]. The deposition of radioactive strontium produces long-term irradiation of bone marrow with secondary anemia and the late development of bone sarcomata. The rats injected with large amounts of radiosulphur and followed until natural death exhibited no increased incidence of tumors or of anemia [14]. The very short range of the radiation precluded an important protracted irradiation of the bone marrow from the adjacent cartilage, even in small animals. The tissue concentration of S^{35} was also progressively reduced by physical decay (half-life: eighty-seven days).

THERAPEUTIC TRIAL OF S^{35}

Introduction

Calculations based on the human tracer studies indicated that intravenously administered S^{35} would deliver much higher doses of irradiation to chondrosarcomata than to the blood. The ratio seemed sufficiently favorable to warrant therapeutic trial in cases of far-advanced chondrosarcomata, even if the maximum possible irradiation delivered by the isotope would probably be too low to eradicate a radioresistant tumor. On this basis, a license for the use of large

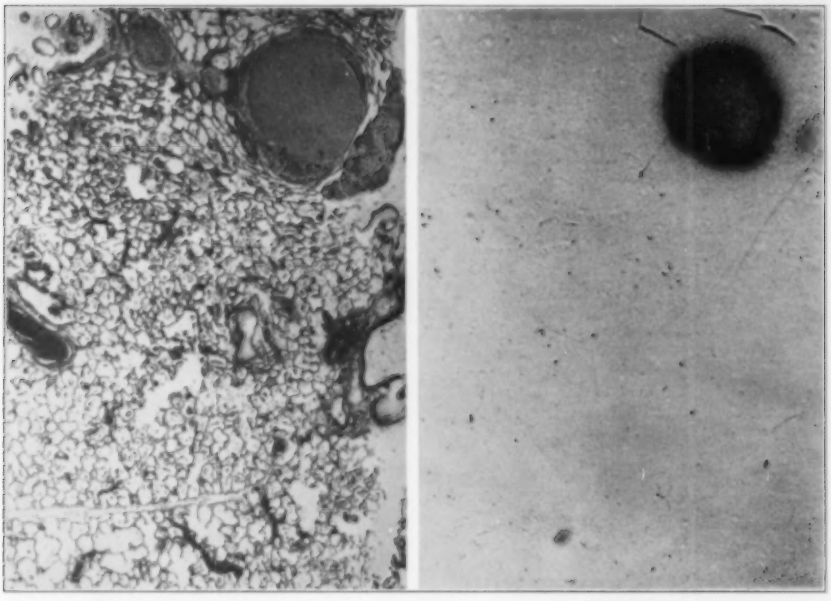

FIG. 5-A FIG. 5-B

Figs. 5-A and 5-B: Chondrosarcoma metastasis in lung of Patient H, autopsy eleven days after S^{35} injection.

Fig. 5-A: Fifteen-micra section, stained with hematoxylin and eosin, reduced from × 23.

Fig. 5-B: Autoradiograph held at distance of about forty micra, 101 days' exposure, same magnification. There is pronounced uptake in the well differentiated intravascular metastasis, but the uptake is very low in the pulmonary tissue. (Reproduced from Gottschalk, R. G.: Fixation of Radioactive Sulfur by Cartilage, Cartilaginous Tumors and Connective Tissue. *In* A.M.A. Scientific Exhibits, 1955, pp. 573–578. New York, Grune and Stratton, 1955.)

amounts of S^{35}-sulphate in cases of unresectable chondrosarcomata was requested and obtained from the Human Application Subcommittee of the United States Atomic Energy Commission.

Methods

The effects of large amounts of S^{35} were studied in three patients with advanced chondrosarcomata. The solutions of radioactive sodium sulphate injected were prepared from isotope received from Oak Ridge National Laboratory, as reported previously [12]. For clinical use, radioactive sodium sulphate is commercially available in injectable form.

After determination of the uptake of tracer injections in biopsied tissues, large amounts of radioactive sulphur were administered in three to six injections at a minimum of weekly intervals. The total amounts given varied from 559 to 926 millicuries. Although somewhat higher dosages were occasionally used, it seems advisable not to exceed 200 millicuries per injection. When moderate leukopenia develops, the interval should be increased to three or four weeks in order to observe the maximum hematological response before the next injection. The control of the dosage is similar to that directing the use of chemotherapeutic agents depressing the bone marrow. Leukocyte and platelet counts should be done at least twice weekly.

The rate of urinary excretion of S^{35} was measured throughout the observations by direct plating and counting of aliquots. The initial excretion should be determined after each injection (normal: 60 to 80 per cent in the first twenty-four hours) in order to control the dosage, since a slower rate of excretion increases the isotope retention and the biological effects.

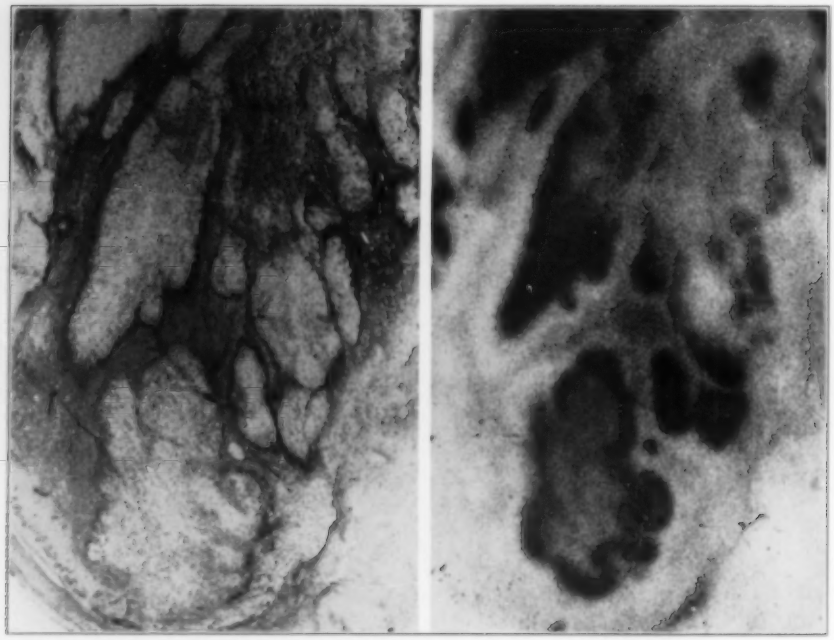

FIG. 6-A FIG. 6-B

Figs. 6-A and 6-B: Chondrosarcoma extending to soft tissues of pelvis of Patient H, eleven days after S^{35} injection.

Fig. 6-A: Six-micra section, stained with hematoxylin and eosin, reduced from × 18.

Fig. 6-B: Contact autoradiograph, 199 days' exposure, same magnification. In the different chondrosarcomatous nodules, a band of greater radioactivity corresponds to the "growing margin" at the time the tracer dose was injected. The proliferating fibrous tissue of the stroma also has an important uptake. The clear zones surrounding the "nodular" deposits of S^{35} in the autoradiograph correspond to the tumor and connective tissue that formed between the time of injection and death, as evidenced by the fact that the radioactive areas are smaller than the corresponding tumor nodules in the photomicrograph. No such displacement of radioactivity was observed in the autoradiographs of tissues obtained soon after injection. (Reproduced from Gottschalk, R. G.: Fixation of Radioactive Sulfur by Cartilage, Cartilaginous Tumors and Connective Tissue. *In* A.M.A. Scientific Exhibits, 1955, pp. 573–578. New York, Grune and Stratton, 1955.)

The short range of the radiation of S^{35} (maximum, 25 centimeters in air) somewhat simplifies the problems associated with the clinical use of large amounts of radioisotopes. The usual precautions of radiological safety should be followed.

Results

The observations on these patients, previously reported [12,13], except for later follow-up data on Patient 2, are summarized as follows:

PATIENT 1 (Chart III), a woman, fifty-nine years old, had a chondrosarcoma primary in the fourth right rib that had been operated on three times since 1955 with removal of part of the chest wall and of the right lung. A recurrence had been treated in December 1957 by x-ray therapy. In March 1958, when large injections of radiosulphur were started, an ovoid mass was present in the axilla, and the edges of the surgical defect were infiltrated by tumor. This anaplastic chondrosarcoma with myxoid and slight chondroid differentiation retained an important fraction of the tracer dose of S^{35} sixty-four hours after injection. The uptake in the tumor (168 per cent) was 4.4 times that in the skin. The patient was given an additional 555 millicuries of radiosulphur in six injections over a period of fifty-seven days. The progressive decrease of the leukocyte count to 2,150 and of the platelets to 60,700 prompted the interruption of the injections. There was no hemorrhagic phenomenon, and the blood counts returned to normal levels. In the eighty days from the first therapeutic injection to discharge from the hospital, the tumors remained about the same size, and the patient's general condition seemed to improve. One month later the chest

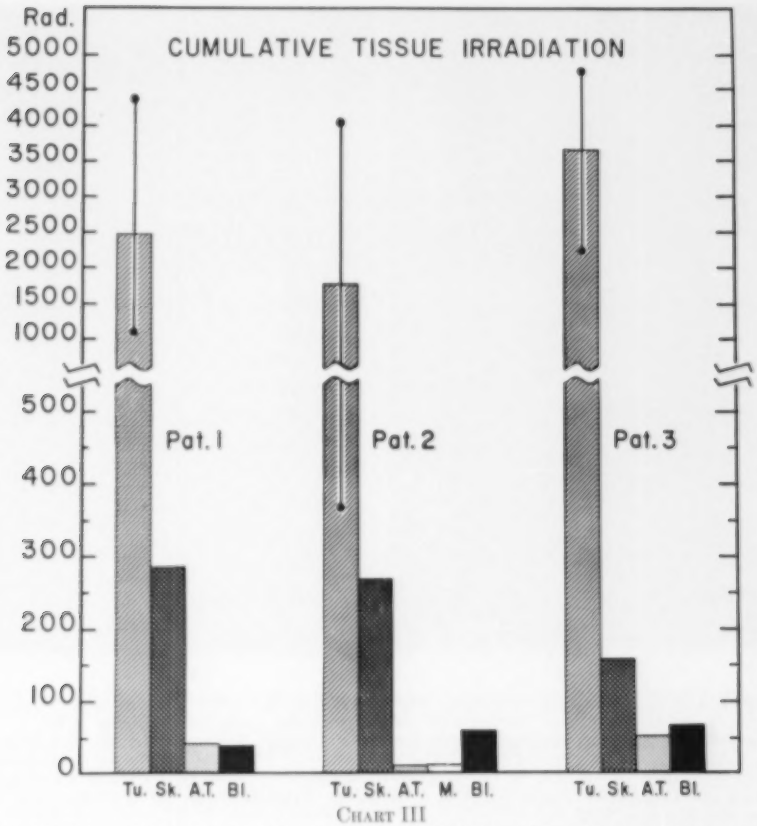

CHART III

Calculated cumulative doses of irradiation (in rad) delivered by therapeutic doses of S^{35}. *Tu.* = tumor; *Sk.* = skin; *A.T.* = adipose tissue; *Bl.* = blood. The maximum and minimum irradiation values for different portions of the chondrosarcomata are indicated by the dots at the tops and bottoms of the vertical lines. Note tenfold change of scale above 500 rad.

tumor started to enlarge and it ulcerated near the site of the previous drainage. It required excision in July 1958. The tumor became fungating, and metastases appeared in the supraclavicular fossa and in bones. The patient died in December 1958, having widespread metastases.

PATIENT 2 (Chart III), a woman, sixty-three years old, had a very large chondrosarcoma surrounding the femur. The diagnosis was established in 1957, but the patient constantly refused surgical removal. The tumor was well differentiated with chondroid and calcified areas. The average uptake of S^{35} in the tumor after a tracer dose of three millicuries (102 per cent) was 3.7 times as high as in cartilage and 9.5 times as high as in the skin. The calcified portions had much lower uptakes than the cartilaginous and growing parts of the tumor (Table II). Five large increments of S^{35}, totaling 923 millicuries, were administered within forty-two days (April to June 1958), bringing the total amount injected to 926 millicuries. A moderate leukopenia, neutropenia, and thrombocytopenia developed, but receded after the series of injections was completed. During the course of treatment, the induration around the tumor decreased. The rate of growth of the tumor since the initial hospitalization was followed on roentgenograms (Chart II). Although there was no regression, the progress of the tumor seemed to be arrested for three months after the beginning of the treatment; during the next three months the growth was still very slow. Then the tumor resumed its original rate of growth. The patient was in good general condition and apparently free of metastasis at the last follow-up in November 1959. A biopsy done at that time suggested some increase in the proportion of degenerated and calcified foci in the chondrosarcoma, but malignant chondroblasts were present*.

* The patient was seen again in April 1960 and in October 1960. The growth of the tumor had continued at about the same rate; it extended far anteriorly and laterally and closer to the knee and to the inguinal fold. The patient was in good general condition.

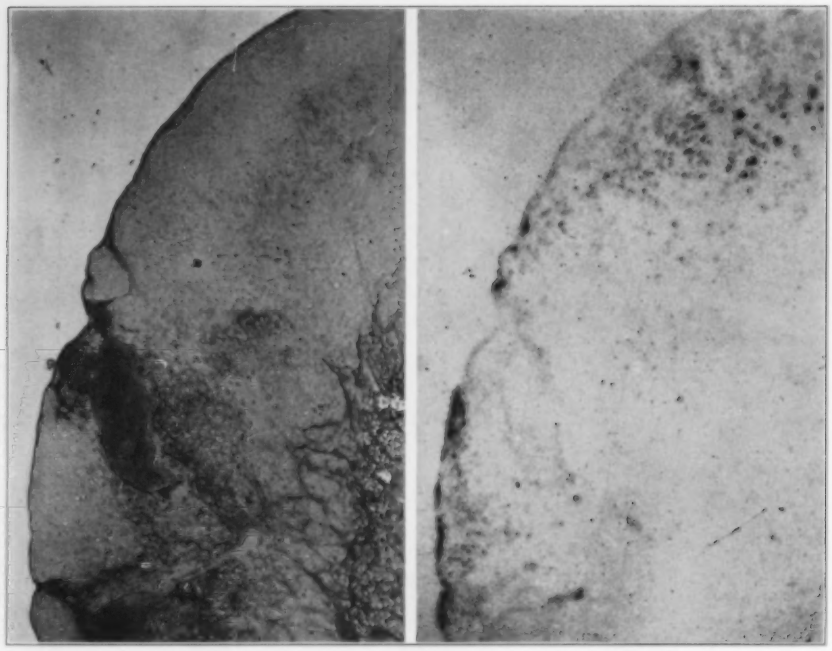

FIG. 7-A FIG. 7-B

Figs. 7-A and 7-B: Intra-articular loose body from Patient B, twenty-six hours after S^{35} injection.
Fig. 7-A: Six-micra section, stained with hematoxylin and eosin, reduced from × 20.
Fig. 7-B: Contact autoradiograph, eighty-four days' exposure. S^{35} is retained near well preserved cells, but not in the degenerated center. A small amount of S^{35} is also fixed in the perichondrium. (Reproduced from Gottschalk, R. G.: Fixation of Radioactive Sulfur by Cartilage, Cartilaginous Tumors and Connective Tissue. *In* A.M.A. Scientific Exhibits, 1955, pp. 573–578. New York, Grune and Stratton, 1955.)

PATIENT 3 (Chart III), a white man, forty-three years old, had a recurrent chondrosarcoma of the seventh left rib with myxoid and slight chondroid differentiation. It was inoperable when diagnosed in October 1957. In May 1958, it distended the entire left side of the chest and displaced the heart far to the right side (Fig. 9-A). Of the three chondrosarcomata treated with large amounts of isotope, his tumor had the largest uptake after the tracer dose (294 per cent, or 11.4 times the skin uptake). Because of the desperate condition, 684 millicuries were administered in three injections at weekly intervals. The hematological effects were enhanced by the slow rate of urinary excretion in this patient with a failing heart, and they became very severe three weeks after the last injection, when the leukocyte count fell to 400 cells per cubic millimeter and the platelets to 7,000. Cutaneous petechiae appeared at this time (Fig. 9-B). Nevertheless, the bone marrow started recovering, and there was no severe hemorrhagic accident or infectious complication. The patient died fifty-four days after the beginning of the isotope treatment. The tumor kept progressing, and the death was clearly due to the widespread neoplasm.

The isotope appeared to inhibit temporarily the progress of the chondrosarcomata in two of the three patients studied. Despite the important uptake of S^{35} in repairing connective tissue, there was no evidence of interference with wound healing. No symptoms referable to any joints were noted. Leukopenia was not accompanied by the symptoms of radiation sickness.

Study of the autoradiographs of the tumors at various time intervals after administration of the isotope showed, at the cellular level, a progressive migration of the isotope from the ground substance immediately adjacent to the chondrocytes to portions of the intercellular ground substance more remote from the cartilage cells (Fig. 4). In the tumors as a whole there was a similar migration

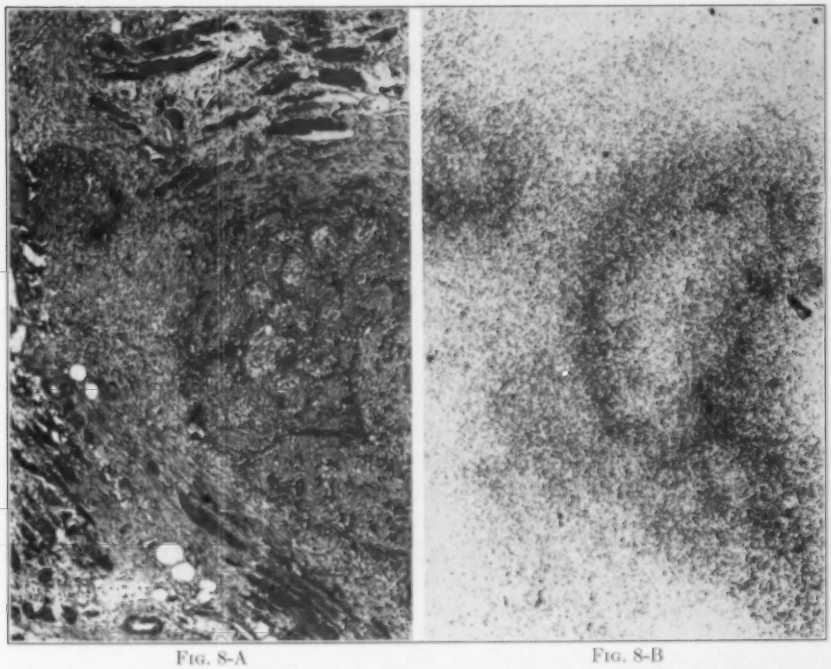

FIG. 8-A FIG. 8-B

Figs. 8-A and 8-B: Fibrous reaction and bone formation in the soft tissues of the hip of Patient C, twenty-two hours after S^{35} injection. This area is close to the callus of a fracture that was nailed and packed with bone chips twelve days earlier.

Fig. 8-A: Six-micra section of decalcified tissue, hematoxylin and eosin, reduced from × 76.

Fig. 8-B: Contact autoradiograph, eighty-four days' exposure. There is general uptake in the young fibrous tissue, and little near the muscle fibers. There is marked uptake at the periphery of the bone and in the adjacent fibrous tissue because of fibroblastic and osteoblastic activity.

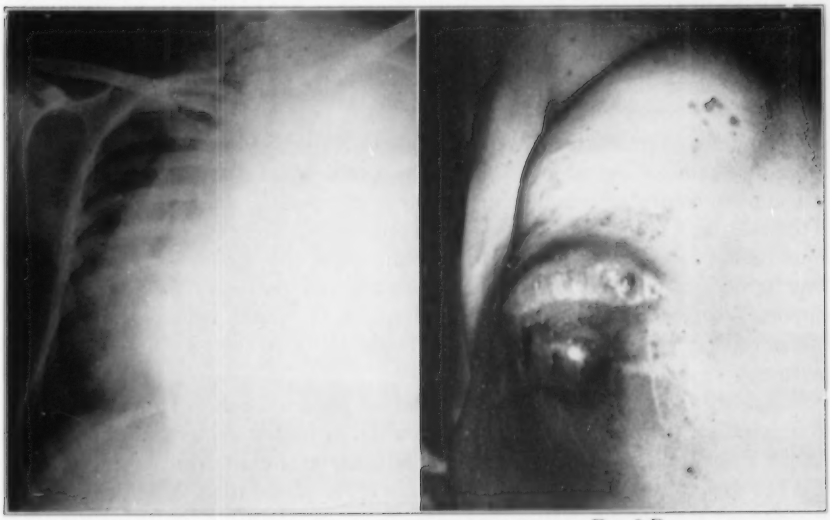

FIG. 9-A FIG. 9-B

Fig. 9-A: Roentgenogram of Patient 3, made on June 9, 1958, during the treatment by injections of S^{35}. The chondrosarcoma has filled the entire left pleural cavity and displaces the heart and trachea far to the right.

Fig. 9-B: Chondrosarcoma protruding under the skin of the back of Patient 3, on July 12, 1958. The skin is markedly congested over the tumor and shows operative scars. Petechiae are visible above the tumor; they had developed nine days earlier and had reached their maximum extent at this time.

of the isotope from the growing edges of the tumors early after injection to some of the necrotic portions of the tumors several months after injection. In the post-treatment biopsy specimens, both nests of actively growing tumor and important necrotic cystic or calcified areas were found. In view of the spontaneous myxoid or calcific degeneration characteristic of chondrosarcomata it was difficult to judge from the morphological evidence how much the presence of the isotope in degenerated tumor foci contributed to the necrosis.

Comment

The dosages of radiation internally delivered by the isotope were calculated from the concentrations found in the tissues [13]. Relatively favorable ratios were observed, since the isotope disappeared more rapidly from the other tissues than from the chondrosarcomata. There was a progressive build-up of the concentration of S^{35} in the tumors with successive injections, whereas the blood concentration fell rapidly to low levels after each injection. Five months after the last injection the concentration in the tumor of Patient 1 was 3,600 times as high as that in the blood. Chart III shows the calculated cumulative doses of radiation delivered up to total decay of the isotope to the tumor, skin, muscle, adipose tissue, and blood. Only about 60 per cent of the calculated dose was delivered to the tumor of Patient 3 because of his early death. In each tumor, maximum concentration of the isotope was found soon after injection in the samples obtained from the growing portions. These areas received doses of irradiation similar to the maximum values indicated in Chart III (4,050 to 4,780 rad). The growing tumor cells frequently received higher doses, in the range of 10,000 rad, because of the short range of the radiation, the localization of radiosulphur around the proliferating chondrosarcoma cells, and the lower isotope concentration in the stroma and acellular areas.

The blood received cumulative doses of 40 to 68 rad. The irradiation delivered to the bone marrow could not be calculated, but it was important, as manifested by the hematological effects. On a body-weight basis, the amounts of S^{35} producing leukopenia in man were lower than in mice and rats. This was related to the slower rate of disappearance of S^{35} from the blood in man than in the smaller species [14].

The doses of irradiation internally delivered to the tumors seemed sufficient to produce radiobiological effects, even in a radioresistant neoplasm. However, for complete control of a malignant tumor it is necessary to arrest the growth of all the cells, and not only of an important proportion. The malignant mesenchymatous tissues forming the stroma or the capsule of the chondrosarcomata had a lower uptake of S^{35} than the chondroid or myxoid portions. This explains the temporary tumor inhibition and the resumption of growth when surviving anaplastic cells begin to multiply and differentiate after termination of the S^{35} treatment.

Haggart and associates regularly obtained palliative relief of symptoms after administration of 6,000 r supervoltage radiation to the centers of chondrosarcomata. Supervoltage irradiation has the advantage of easier control and of complete coverage of the field by higher average tumor doses than those delivered by S^{35}, although the isotope irradiation of individual proliferating tumor cells is often higher. Supervoltage therapy has produced some regressions of localized tumors, whereas only a temporary inhibition of growth was observed after radiosulphur. On the other hand, radioactive sulphur, because of its metabolic affinities, can irradiate primary and metastatic tumor cells in varied locations without the restrictions imposed by the size of the fields of irradiation.

CONCLUSION

The ability of cartilage and chondrosarcomata to retain radioactive sulphur and the destruction of growing epiphyseal cartilage by large amounts of S^{35} provided the basis for therapeutic trials in three cases of unresectable chondrosarcomata. Although there was no definite tumor regression, in two patients the progress of the tumors was arrested or markedly slowed down for several months after the beginning of the treatment. It will be necessary to observe the effects of large amounts of S^{35} on a larger number of chondrosarcomata to determine whether a significant palliation can be obtained in a sufficient number of cases to warrant the clinical use of S^{35}*. Radioactive iodine, which is presently the most useful isotope for systemic administration in cancer therapy, is of value only in a small proportion of the cancers of the thyroid gland[19].

As with other radioactive isotopes and with some chemotherapeutic agents, the amounts of radioactive sulphur that can be administered are limited by the hematological effects. Since the development of severe leukopenia and thrombocytopenia may be delayed for two or three weeks after the administration of S^{35}, the use of large amounts of S^{35} can be justified only in cases of far-advanced chondrosarcomata.

The chances of obtaining a significant inhibition of the tumor depend on the relative uptake in the tumor and blood-forming tissues, and on the radiosensitivity of the tumor. In our experience, all tumors microscopically diagnosed as chondrosarcomata had important uptakes of radioactive sulphur because of the presence of ground substance. Since the irradiation delivered to the chondrosarcomata was due in great part to the long biological half-life of S^{35} in cartilaginous tissues, it is possible that the radiosensitivity of the tumors may be a more important factor in their response than the initial ratio of isotope uptake.

The tracer studies demonstrated gross and microscopic patterns of fixation of radioactive sulphur in cartilaginous tumors susceptible of therapeutic application. The use of large amounts of S^{35} is still experimental and has achieved, at best, only temporary tumor inhibition. In view of the possible long-term detrimental effects of large doses of any form of ionizing radiation and of the limited experience with radioactive sulphur, its use must be limited to patients with widespread tumors who have a fatal prognosis with established therapeutic methods.

SUMMARY

Radioactive sulphate is selectively retained in chondrosarcomata, chondromata, and normal cartilage as well as in repairing connective tissue and bone. The observations after intravenous injection of tracer doses are described in five cases of chondrosarcoma and in one of anaplastic sarcoma.

The patterns of localization of S^{35} in chondrosarcomata, chondromata, granulation tissue, and bone are demonstrated by autoradiographs.

Counts obtained on the surface of excised tissues gave a crude index of their isotope content. Accurate determination requires chemical analysis.

After the destruction of growing epiphyseal cartilage by large amounts of S^{35} was observed in experimental animals, radioactive sulphate was administered at therapeutic levels to three patients having advanced chondrosarcomata. The progress of the neoplasms seemed markedly reduced or arrested for several months in two of these patients.

* Andrews and associates[1], in a paper published shortly before this meeting, reported the effects of 1,000 millicuries of S^{35}-sulphate in one patient with chondrosarcoma. The bone marrow was severely depressed but recovered. There was clinical improvement and cessation of the growth of the tumor for five months. The tumor growth was resumed at a later date.

The calculated doses of radiation internally delivered by the isotope to the chondrosarcomata were much higher than those delivered to other tissues.

NOTE: Mrs. R. P. Mudd, Miss F. A. Garrett, and Mr. J. F. Szafir, of Houston, Texas, and Mrs. P. O. Miller, Mr. P. Bell, and Mr. H. Grantham, of Martinsburg, West Virginia, gave skilled technical assistance. Our thanks are due to Mr. H. Busey, of Martinsburg, West Virginia, for photographic-illustration work.

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DISCUSSION

DR. MARK B. COVENTRY, ROCHESTER, MINNESOTA: Dr. Gottschalk has related to us his experiences with radioactive sulphur. This isotope has been demonstrated to localize first in the chondrocyte and then to appear in the ground substance, or cartilaginous matrix, surrounding the cell. Its concentration, when injected into man, is higher in cartilage than in other tested tissues and is highest in chondrosarcoma. This had led logically to its trial as an oncolytic agent in chondrosarcoma. We have heard the result of its use in three patients suffering from advanced, inoperable chondrosarcoma. Experience with a fourth patient has been recently reported by Andrews and his associates in the American Journal of Roentgenology, Radium Therapy and Nuclear Medicine for January 1960.

Dr. Gottschalk's paper has been reviewed by my colleagues in the Section on Therapeutic Radiology and the Section on Biochemistry at the Mayo Clinic. My subsequent remarks will include their thoughts as well as my own.

The therapeutic effects of S^{35} are limited by the following factors: (1) the toxic effect of S^{35}, if it is used in large enough doses to be truly lethal to chondrosarcoma cells, depresses the hematopoietic system to such an extent that death of the organism occurs; (2) the localization of S^{35} is spotty so that even with near-lethal doses, certain tumor cells will probably escape; and (3) chondrosarcoma is notoriously a radioresistant tumor.

These limitations might, in part at least, be overcome by the following methods: Techniques for the transplant of autogenous bone marrow, if successfully accomplished, could result in the administration of far higher concentrations of S^{35}. Some chondrosarcomata are more able to concentrate the radioactive isotope than others. Measurement of the ratio of uptake of S^{35} with tracer doses, therefore, would separate tumors into those that might be expected to respond to this form of treatment and those that would not, and this would allow us to concentrate our efforts on the more sensitive tumors. Focal x-ray therapy could be used to supplement the radiation dose from the isotope without adding to the burden on the bone marrow. Furthermore, since S^{35} is a beta emitter, the radiation throughout the tumor might be uneven, and supplemental focal irradiation would increase the dose to areas in which there is a low beta dose. Perfusion techniques might be applicable. This would allow for a very high dose of S^{35} to be placed in the circulation of an extremity containing a chondrosarcoma. The uptake by the tumor might be adequate in this instance without suppression of the bone marrow in the rest of the body; however, when perfusion can be used, amputation can also be used, as a rule.

This is a valuable and timely paper, and Dr. Gottschalk deserves our gratitude for bringing this work to us and our encouragement in further research in this field. He has not presented a cure for chondrosarcoma. Indeed, he has not demonstrated that S^{35} is even a very useful adjunct in its treatment, yet there is a promise that if some of these problems that we have discussed can be solved, radioactive sulphur may prove to be a most helpful agent in the treatment of chondrosarcoma.

Dr. Gottschalk (closing): Since the product is injected into the veins, the isotope can reach the tumor anywhere it is located. However, as mentioned by the discussor, the uptake is variable, and not every focus of chondrosarcoma has the same uptake. For the general problems of the use of radioactive sulphur, I do not think that we have here any magic bullets, but I think that the search is on for a magic bullet, even if it is deceiving.

The same problem has arisen with respect to carcinoma of the thyroid, of which only a small fraction concentrates and responds to radioactive iodine. The proportion is better in chondrosarcoma in regard to the uptake—I do not say in regard to the therapeutic response—since we do not diagnose a tumor as chondrosarcoma unless it has ground substance. Otherwise, we just call it anaplastic sarcoma. If the tumor forms ground substance, it has at least some uptake of radioactive sulphur, but it is far from certain that this uptake will be sufficient to kill the tumor cells.

What we would like to have is extension of similar observations. The paper by Andrews and associates, which was mentioned in the discussion, just came out in print this month. The authors are somewhat more positive than we are about their results. They describe cessation of growth of the chondrosarcoma and healing of the ulceration for five months in one patient who received 1,000 millicuries. In fact, our studies are somewhat similar inasmuch as we did some experimental work at the beginning in collaboration.

Concerning methods to increase the biological effectiveness of radioactive sulphur, we thought about bone-marrow transplantation, but did not do it. We have considered regional perfusion with radioactive sulphur, especially for Patient 2 at the recent follow-up. However, if one considers the metabolism of radioactive sulphur, the advantages of perfusion over intravenous injection may be quite limited, owing mainly to the fact that radioactive sulphur is relatively slowly picked up from the blood, contrary to nitrogen mustard, which disappears very rapidly from the blood. There are two other methods, as yet unpublished, that we have tried. One is local injection into the tumor; it was not rational, but it was worth trying. One does not obtain any higher uptake by local injection than by intravenous injection. The last method, which might have the most physiological basis, was to inject human pituitary growth hormone together with the radiosulphur. This, in principle, is similar to the injection of radioactive iodine together with thyroid-stimulating hormone. The results on the use of growth hormone are being analyzed, and I cannot give final conclusions.

Congenital Recurvatum of the Fibula

Report of One Case

BY ERIC J. ROTHSCHILD, M.D., WILLIAM P. HOWLEY, M.D., AND JOHN C. McCAULEY, JR., M.D., WEST HAVERSTRAW, NEW YORK

From the Orthopaedic Service, New York State Rehabilitation Hospital, West Haverstraw

Congenital absence and hypoplasia of the fibula have been recorded by Kite and by Coventry and Johnson. Various types of congenital angulation of both long bones of the leg have been described by Badgley, O'Connor, and Kudner, Heyman and Herndon, Krida, and Lapidus. However, a review of the literature fails to reveal documentation of a case of posterior bowing of only the fibula without associated tibial or foot deformities. Therefore, the case to be described seems to warrant being recorded.

Fig. 1

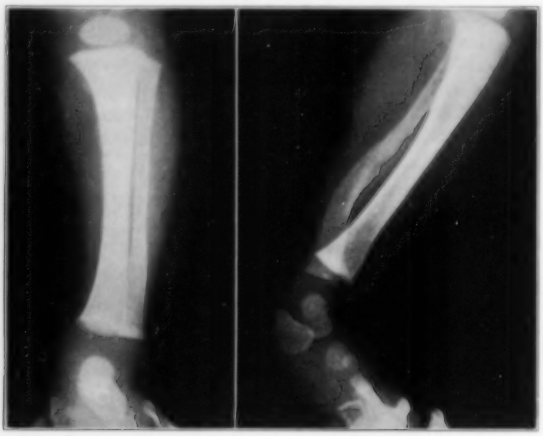

Fig. 2

Fig. 1: Lateral roentgenogram of the left leg when the patient was two weeks old showing posterior bowing in the lower third and slight anterior bowing in the upper two thirds of the fibula, as well as expansion of the anterior cortex of the fibula in the middle third. Note that the tibia and foot are normal.

Fig. 2: Anteroposterior and lateral roentgenograms of the left leg when the patient was three months old shows a slight decrease in the bowing of the fibula. Note the essentially normal appearance of the fibula in the anteroposterior projection.

R.R., a white boy, was seen shortly after birth because of a deformity of the second toe on the left foot with lateral deviation of this digit under the third toe. History revealed that the father has a hammer-toe of the second toe of the right foot exactly similar to that of the child. In addition the father had had a foot ailment as a child which was treated in plaster with good results. Unfortunately, hospital records are not available and the nature of this ailment is not known.

General examination of the child, excluding the left lower extremity, revealed no abnormality except for mild deformation of the right ear. No *café au lait* spots or other stigmata of neurofibromatosis could be found. The father had a similar deformity of the right ear. Clinical examination of the foot revealed lateral deviation of the second toe under the third toe. It was also noted that the left fibula was bowed posteriorly. There was no clinical evidence of deformity of the foot.

Roentgenograms of the left leg and foot revealed posterior bowing in the lower third of the fibula sufficient to form an angle of approximately 35 degrees and a mild anterior bow in the upper two-thirds of the fibula. The anterior cortex of the fibula just proximal to the posterior bow was expanded with slight irregularity of the bone architecture (Fig. 1). There was no roentgenographic

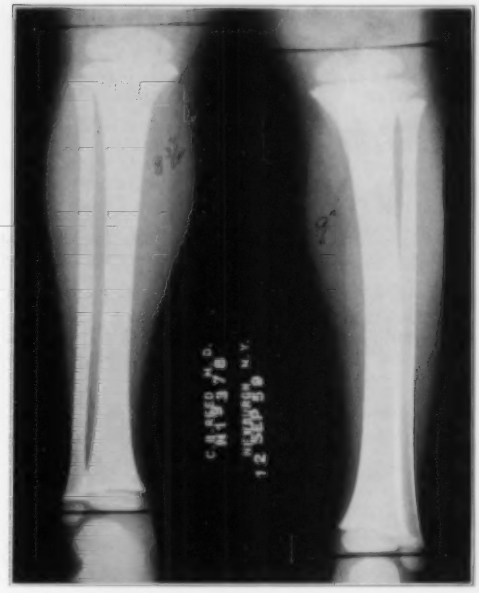

FIG. 3

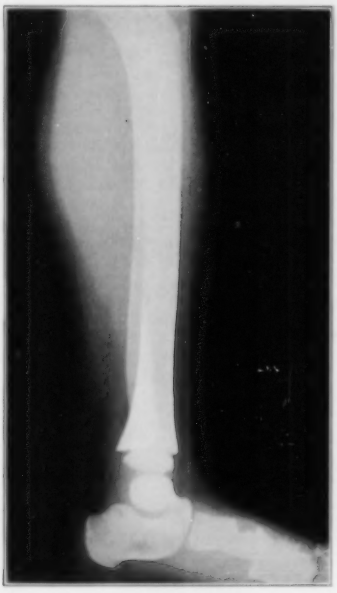

FIG. 4

Fig. 3: Scanogram made when the patient was three and a half years old shows one-quarter of an inch of increased length together with very slight thickening and lateral bowing of the tibia on the affected side.

Fig. 4: Lateral roentgenogram of the left leg made when the patient was three and a half years old shows correction of posterior bowing.

evidence of associated deformities of the foot or tibia. Scanograms showed no disparity in leg lengths.

A plaster boot was applied to the lower leg and foot for two months on the assumption that this would prevent the development of a valgus deformity of the foot. Tape was applied to the second toe in an attempt to correct its deformity, but the toe could not be maintained in the corrected position and no correction was obtained after prolonged use of strapping. Roentgenograms obtained approximately five months and one year after the initial examination showed a decrease of approximately five degrees in the posterior bowing of the fibula at each examination (Fig. 2). On follow-up two and one half years after the initial examination the posterior bowing of the fibula had decreased to approximately 15 degrees. During this time the patient grew normally and clinical observation revealed no deformity in the foot or leg. Scanograms of the tibia and fibula showed one-quarter of an inch increased length on the affected side at the age of two and one-half. The patient was again examined when three and one-half years old and at that time the posterior bowing of the fibula had almost completely resolved (Fig. 3), but the one-quarter of an inch disparity in leg length by scanogram persisted. The patient is now four years old; he walks well, with no clinical deformities except for the lateral deviation of the second toe. Mental development and physical growth are normal for his age.

The occurrence of this deformity of the fibula, its lack of association with any other deformities, and its spontaneous correction during growth are noteworthy. The course and favorable prognosis of this deformity are similar to the course and prognosis of posterior angulation of the tibia, as described by Krida. This similarity suggests a common denominator in the pathogenesis of these deformities but major shortening of the affected extremity, a predominant factor in tibial angulation, is not evident in this case, but will be closely watched for in the future.

SUMMARY

A case of isolated posterior recurvatum of one fibula without associated

deformities is reported which has progressed to spontaneous resolution during growth. A similarity to posterior angulation of the tibia is implied.

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DISCUSSION

Management of Fractures of the Carpal Navicular

(*Continued from page 1190*)

each wrist or hand to check routinely the relationship between the proximal heads of the first and second metacarpals, as this relationship is usually disturbed when the greater multangular is fractured. Oblique views are then indicated and will usually demonstrate the fracture line quite well.

The greater tubercle of the greater multangular lies on its volar aspect and exhibits, on its basal and ulnar sides, a deep groove within which lies the tendon of the flexor carpi radialis muscle. The tubercle sometimes produces an impression of a fracture fragment on roentgenograms. As Dr. Cordrey indicates, there is no good way of demonstrating the volar aspect of the greater multangular on roentgenograms. The lack of displacement of the carpometacarpal joint usually serves to rule out a fracture and there is no pain on resisting the flexor carpi radialis, as one would expect with a fracture of the tubercle.

The authors have demonstrated that good results can be realized with a good reduction of the fracture and proper immobilization. I agree that fractures of the greater multangular that are displaced and cannot be manipulatively reduced and maintained should be treated by open reduction. Fixation with Kirschner wires provides an excellent method of immobilization.

I prefer a volar radial incision extending vertically along the proximal third of the first metacarpal, with reflection of the thenar muscles from the metacarpal and the capsule of the carpometacarpal joint. Excellent exposure is realized without danger of trauma to the cutaneous branches of the radial nerve or the radial artery.

Osteochondrosis of the Distal Tibial Epiphysis

A Report of Two Cases

BY WILLIAM L. HASSLER, M.D., CLARENCE H. HEYMAN, M.D.,
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From the Services for Crippled Children, Elyria Memorial Hospital, Elyria

As early as 1907, Hardivillier pointed out the similarities between the various disturbances that occur in the epiphyses. Before his report and for many years to follow, these disturbances were known as individual diseases and they still bear the name of their earliest proponents [4]. Legg-Calvé-Perthes disease of the hip, Osgood-Schlatter disease of the tibial tubercle, and many other diseases have now come to be classified together as osteochondroses because of the similarity of their clinical progression and roentgenographic appearance and their mys-

FIG. 1-A

Case 1. Roentgenograms made when the patient was three and a half years old. Views of the right leg show anterior bowing of the tibia and congenital absence of the proximal third of the fibula. Only the anteromedial half of the distal tibial epiphysis has appeared, but its trabecular pattern is fairly normal.

terious etiology. The degeneration of the osteochondral growth centers occurs in a manner similar to avascular necrosis that is known to be secondary to disruption of the blood supply. The underlying circulatory disturbance in the osteochondroses has been attributed variously to trauma, low-grade infection, excessively rapid growth of the epiphysis, and even to endocrine disturbances [3,5,6].

The many different epiphyses in which the osteochondroses have been observed are recorded in Caffey's textbook of radiology [2], where twenty-two

FIG. 1-B

Roentgenograms made when the patient was seven and a half years old. The posterolateral half of the distal tibial epiphysis has appeared and is flattened and somewhat fragmented. There are marked cystlike changes in the metaphysis adjacent to the epiphysis.

FIG. 1-C

Roentgenograms made when the patient was ten years old. The distal epiphysis is now deeper and has a better trabecular pattern. The epiphyseal line appears to be open, and the cystic changes in the metaphysis are filling in.

different areas of involvement are listed. One site of occurrence to which prior published reference has not been found, to our knowledge, is the distal tibial epiphysis, although avascular necrosis at this site after fracture of the epiphysis has been reported [7]. A single case, thought to be the first in print, of non-traumatic avascular necrosis of the proximal tibial epiphysis was recorded in 1954 [1]. The purpose of the present communication is to report two patients seen at the Elyria Memorial Hospital Crippled Children's Clinic in which the findings were consistent with the diagnosis of osteochondrosis of the distal tibial epiphysis.

CASE 1. R. S., a Caucasian girl, was first seen in 1950 when she was thirteen months old; there was shortening of her right lower extremity below the knee because of congenital anterior bowing of the tibia and absence of the proximal one-third of the fibula. She also had a severe valgus deformity of the ankle that was apparent when she stood. Roentgenograms made when she was eighteen months old showed the abnormalities of the tibia and fibula as well as delayed develop-

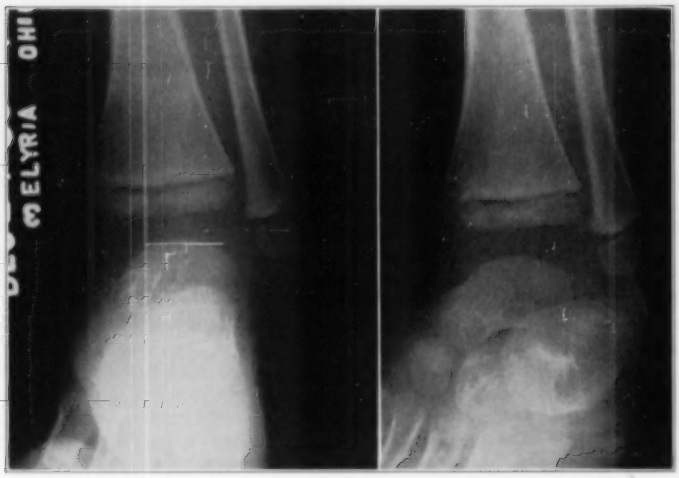

FIG. 2-A

Case 2. Anteroposterior and oblique roentgenograms of the left ankle made when the patient was five years old. The distal tibial epiphysis is flattened and fragmented, especially in the oblique view. The metaphysis is broadened, and there is sclerosis adjacent to the epiphyseal plate.

FIG. 2-B FIG. 2-C

Fig. 2-B: Oblique roentgenograms of both ankles made when the patient was six years old. The left distal tibial epiphysis has increased in height, and the trabecular pattern is slightly better than that of a year ago. Compare the appearance of this epiphysis with that of the opposite distal tibia.

Fig. 2-C: Anteroposterior roentgenogram of the left distal tibia, made when the patient was eight years old, showing the excellent remolding of the epiphysis. The metaphysis is still broadened, and the medial malleolus has not yet appeared.

ment of the distal tibial and fibular epiphyses. When the patient was three and a half years old, the anteromedial half of the distal tibial epiphysis appeared. It presented a fairly normal trabecular pattern (Fig. 1-A). At this time the child was walking in a knee-to-ankle brace that was worn to control the valgus deformity of the ankle. When the patient was seven and a half years old, roentgenograms showed fragmentation of the distal tibial epiphysis, especially of its posterolateral half, which had appeared after the patient was three and a half years old. There were also marked cystic changes in the metaphysis (Fig. 1-B). The patient had no symptoms referable to the ankle when walking with or without her brace, although there was notable widening of the ankle by clinical examination. Two years later, the roentgenogram showed beginning re-formation of bone trabeculae in the epiphysis, and, at the time of writing, when the patient was ten years old, trabeculation was much more uniform, and the cystic areas in the metaphysis were far less prominent (Fig. 1-C). At the time of writing, the patient had no pain and walked well in her brace. An elevated shoe was necessary because of shortening of two and one-quarter inches of the extremity secondary to congenital bowing of the tibia.

CASE 2. D. H., a Caucasian boy, was first seen in 1953 when he was two years old. There was a mild spastic right hemiplegia and a mild recurrence of a left metatarsus adductus deformity that had been treated only by manipulations at home. During the next three months, there developed a valgus deformity of the right foot that eventually required the use of a brace. When the child was three years of age, his left medial malleolus was noted to be quite prominent, although asymptomatic. Roentgenograms revealed that ossification of the distal tibial epiphysis had not occurred, and that the distal fibular epiphysis was smaller than that on the right. Additional roentgenograms of the skeleton revealed no other epiphyseal abnormalities. During the next several months, the left foot showed a tendency to go into varus position. When the patient was five years old, roentgenograms showed ossification of the distal tibial epiphysis, but the epiphysis was flattened and fragmented. The adjacent metaphysis was broadened and showed increased juxta-epiphyseal sclerosis (Fig. 2-A). After the patient had used a brace for one year to control the varus deformity of the left ankle, no further fragmentation of the epiphysis had occurred, and the bone showed a more normal trabecular pattern. Some deformity of the talus had developed (Fig. 2-B). At the time of writing the patient was eight years old and was walking in a regular shoe. Roentgenograms showed the distal tibial epiphysis to be of essentially normal shape and architecture, although the metaphysis was still somewhat broad, and the talus was slightly abnormal in configuration (Fig. 2-C).

DISCUSSION

Both patients showed similar clinical and roentgenographic features, although the patient in Case 1 had the complication of accompanying congenital deformities in the same limb. Perhaps neither case would have come to light were it not for the patients' other orthopaedic problems. As the patients were followed through the years, clinically and by roentgenograms, both showed progressive changes typical of an osteochondrosis. The first, or incipient, stage of soft-tissue swelling and hyperemia was most prominent in the second patient, where it drew attention to the area before the epiphysis had even begun to ossify. The pain characteristic of this phase of the disease was not a significant finding in either of these two patients, perhaps because they both had physical limitations that restricted their activities. The second, or active, stage of fragmentation and cystic degeneration lasted about two years in each patient and resulted in flattening and broadening of the epiphysis typical of an osteochondrosis involving a weight-bearing epiphysis. The third, or healing, stage took about two years in the second patient and resulted in an epiphysis that was normal in appearance except for the absence of the medial malleolus. At the time of writing the first patient appeared to be improving, although the final configuration of the distal epiphysis will, no doubt, be affected by the anterior bowing of the tibia as well as the transient osteochondrosis.

SUMMARY

Two cases have been presented in which the clinical course and progressive roentgenographic changes were strongly suggestive of osteochondrosis of the distal tibial epiphysis, an occurrence that is unusual, if not rare.

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Proceedings

AMERICAN MEDICAL ASSOCIATION: SECTION ON ORTHOPAEDIC SURGERY

As Prepared by Robert J. Joplin, M.D., Secretary, Section on Orthopaedic Surgery

The 1960 Annual Meeting of the Section on Orthopaedic Surgery of the American Medical Association was held in Miami Beach, Florida, June 13 through 17, 1960. A brief review of the sessions and a résumé of each paper follow.

The meeting on Tuesday, June 14, was held at the Hotel Fontainebleau. The following papers were presented and discussed:

Shoulder Arthrography. Dr. Robert L. Samilson [1], Dr. Robert L. Raphael, Dr. Lawrence Post, Dr. Charles Noonan, Dr. Evelyn Siris, and Dr. Frank L. Raney outlined a method of shoulder arthrography (utilizing intracapsular injection of 25 per cent hypaque). The findings in normal shoulder arthrograms obtained by this method were described in detail. The method was applied to 125 shoulders without resultant infection. It was the authors' opinion that the method was safe, easy, and could be done on an out-patient basis.

Consistent pathological patterns in tears of the rotator cuff, in lesions of the bicipital tendon, in dislocation of the shoulder, and in frozen shoulder were demonstrated and discussed.

The authors feel that the future in shoulder arthrography and cinearthrography is promising. Investigations in cinearthrography are being continued, and it is hoped that in future studies much more will be learned about the function and pathology of shoulder joints.

Skeletal Anomalies Associated with Syringomyelia, Diastematomyelia, and Myelomeningocele. Dr. James W. Gardner [2] and Dr. John S. Collis contended that in the adult with syringomyelia, as in the adolescent with diastematomyelia and the infant with myelomeningocele, the skeletal anomalies are similar, although progressively more severe, in that order. The skeletal anomalies consist of scoliosis, dilatation of the spinal canal, spina bifida, hemivertebrae, fused vertebrae, deformed ribs, and deformed feet. The associated anomalies of the spinal cord in these three conditions are also similar and progressively more severe in the same order. The anatomical evidence suggests that a varying degree of overdistention of the embryonic neural tube is the cause of these three clinical states.

The Klippel-Feil syndrome, syringomyelia, diastematomyelia, myelomeningocele, inencephaly, and combined anterior and posterior spina bifida with posterior gut fistula can all be explained on the basis of a single defect occurring in embryonic life—namely, hydrocephalomyelia due to inadequate permeability of the rhombic roof, that is, embryonal atresia of the fourth ventricle.

Diastematomyelia with Acquired Club-Foot Deformity. Dr. Clyde W. Dawson [3] and Dr. John H. Dreisbach reported two cases of diastematomyelia with associated club-foot deformities and suggested a better understanding of the potential neurological abnormalities associated with this condition. Early surgical treatment to correct these abnormalities would prevent the development of deformities of the lower extremities. The abnormalities in diastematomyelia were reviewed, along with the characteristics in this condition that lead to irreversible cord changes. The authors discussed the relationship of club-foot deformity to diastematomyelia and stressed the importance of early diagnosis and correction of the neurological lesions. Neuromuscular imbalances in the lower extremities in children who have not benefited by early neurosurgical intervention can be corrected by standard procedures. The procedures will give these children normal gait and stance even when the neurological changes are not reversible.

Congenital Plantar-Flexed Talus (Congenital Dislocation at the Talonavicular Joint). Dr. Frederick S. Craig [4] said that early reduction of the talus, before the development of bone deformity, when the patient is one or two years of age, gives the best final results in the treatment of so-called congenital plantar-flexed talus. He pointed out that the extensive anterior

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4. 180 Fort Washington Avenue, New York 32, N. Y.

release with possible injury to the nutrient artery in the neck of the talus and damage to the vessels of the sinus tarsi may result in aseptic necrosis of the talus. Internal fixation by wire, or by talonavicular arthrodesis, or by a combination of both procedures, is considered essential. A metal arch support made from a mold of the corrected foot should be worn until it is established that the talus is stable. The author believes that the plantar-flexed talus is caused by a congenital dislocation of the talonavicular joint. The treatment should be directed first to the release of the contracted dorsal structures which maintain the dislocation, and then to the alignment of the fore part of the foot with relation to the talus in plantar flexion. Loss of alignment is best prevented by internal fixation; correction by manipulation and immobilization in plaster is usually impossible in the treatment of these anomalies.

Surgical Aspects of Rheumatoid Arthritis and Lesions Simulating Rheumatoid Arthritis was a combined television program and panel discussion. The participants were: *Moderator,* Dr. Edward W. Cullipher[5], *Operating Surgeons,* Dr. Lester A. Russin[6] and Dr. William S. Weinkle[7], *Panelists,* Dr. Richard H. Freyberg[8], Dr. Lee Ramsay Straub[9], and Dr. J. Leonard Goldner[10].

The program was part of a color television program which originated from the Mt. Sinai Hospital and was sponsored and produced by Smith, Kline and French Laboratories of Philadelphia.

Projected on the screen was a hip fusion performed for the treatment of osteo-arthritis caused by an old dislocation of the hip. A concurrent panel discussion was interrupted from time to time to show the progress of the operation.

Dr. Straub demonstrated, by color slides, lesions produced by rheumatoid arthritis in the hands. Dr. Goldner, also using color slides, showed lesions which may simulate rheumatoid arthritis in the hands and feet, but which are actually not rheumatoid arthritis. Dr. Freyberg discussed the rheumatoid factor, which has recently been discovered.

The Second Executive Session on Orthopaedic Surgery was opened on Wednesday, June 15. The first order of business was the election of officers. The following slate was presented by the Nominating Committee and unanimously elected:

Chairman of Section: James I. Kendrick, M.D., Cleveland, Ohio;
Vice-Chairman: James Vernon Luck, M.D., Los Angeles, California;
Secretary: Robert J. Joplin, M.D., Brookline, Massachusetts;
Assistant Secretary: John C. Wilson, Jr., M.D., Los Angeles, California;
Delegate: Edward L. Compere, M.D., Chicago, Illinois;
Alternate Delegate: Harry R. Walker, M.D., Oakland, California;
Representative to Scientific Exhibit: E. Burke Evans, M.D., Galveston, Texas;
Assistant Representative to Scientific Exhibit: J. William Fielding, M.D., Dumont, New Jersey;
Representatives to American Board of Orthopaedic Surgery: John Royal Moore, M.D., Philadelphia, Pennsylvania, and Frank E. Stinchfield, M.D., New York, N. Y.

After the Business Session the following papers were presented:

Surgical Fixation of Small but Important Bone Fragments with the Hookplate; Review of a Method Used in the Last Ten Years in About 450 Cases (Mainly Involving Joint Fractures of the Ankle and Elbow). Dr. Wilhelm A. Zuelzer[11] described what he calls a "hookplate", which is made of malleable, surgically acceptable metal that can be bent with a pair of pliers to correspond with the contour of the bone; the hooks grasp the fragments securely by surrounding it slightly.

The author described the principle of the hookplate fixation of small but essential bone fragments, stressing the grasping action of the hooks and the fixation afforded by the screws inserted in healthy cortical bone at 90 degrees to the direction of the main displacing force. The method has proved to be of special value in the treatment of comminuted fractures of the medial malleolus and the olecranon and in the fixation of fragments of osteoporotic bone.

The author used this device in over 450 fractures, mainly those of the ankle joint and olecranon, and did not routinely remove the plate.

Partial Sciatic Palsy in Premature Infants. Dr. Paul H. Curtiss, Jr.,[12] and Dr. Howard

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6. 975 Arthur Godfrey Road, Miami Beach 40, Florida.
7. 975 Arthur Godfrey Road, Miami Beach 40, Florida.
8. 535 East 70th Street, New York 21, N. Y.
9. 535 East 70th Street, New York 21, N. Y.
10. Duke University Hospital, Durham, North Carolina.
11. DeWitt Army Hospital, Fort Belvoir, Virginia.
12. 2065 Adelbert Road, Cleveland 6, Ohio.

J. Tucker discussed the occurrence of sciatic-nerve injury in ten premature infants after intragluteal injection of medication. All but one patient regained a functional level of active dorsiflexion in from 1.5 to seven months (average, 4.06 months). In six patients, however, there developed a mild, easily correctible, equinovarus deformity; all but one showed one to two centimeters shortening of the involved foot.

The ventrogluteal site of von Hochstetter and the lateral thigh were suggested as preferable areas for intramuscular injections.

An End-Result Study of Congenital Clubfeet Treated at the Alfred I. duPont Institute. Dr. A. R. Shands, Jr.[13], Dr. G. Dean MacEwen, and Dr. Daniel J. Scott described 137 children with club-foot deformity seen at the Alfred I. duPont Institute from 1940 to 1960. Sixty-two of these patients with a follow-up of at least five years were evaluated. On clinical examination, 39.6 per cent were found to have excellent results; 32.3 per cent, good; 4.2 per cent, fair; and 23.9 per cent, unacceptable results. Roentgenograms were reviewed and emphasis was placed on the causes of recurrences and failures.

The authors found that plaster-cast treatment of club-foot deformity gave good or excellent results with serviceable and mobile feet in a high percentage of patients. They concluded that plaster-cast therapy should be started at the earliest sign of recurrence and that this treatment is of value in the older child if the deformity is a true recurrence and not a residual deformity.

Night splints were very important in preventing recurrences, but night splints would not correct residual deformities or significantly decrease recurrences already present.

The Infant's Hip—Normal or "Dysplastic"? Dr. Charles T. Ryder[14], Dr. John P. Caffey, and Dr. Gilbert W. Mellin examined 1,000 unselected infants clinically and roentgenographically to test the hypothesis that clinical and roentgenographic signs in infancy—particularly, limited abduction and high acetabular angle—indicate a dysplasia which requires treatment to prevent later dislocation. None of these patients was treated, and all had normal hips when re-examined at one or two years of age. The authors believe that signs of so-called dysplasia may well be seen in infants whose hips are normal. Routine re-examination of the hips as the infant grows will detect the not-uncommon acquired subluxation. If the roentgenograms show no displacement, it is most unlikely that the acetabulum is in fact abnormal; other than careful periodic re-examination, treatment for such hips is not necessary.

Surgery of the Extremities in the Treatment of Cerebral Palsy. Dr. Sidney Keats[15] said that comprehensive treatment for the rehabilitation of a child with cerebral palsy now requires the integrated service of a team of specialists to ensure not only physical restoration but optimum psychological, educational, and social restoration of the patient. Dr. Keats believes that surgery on the extremities has a definite role in the over-all treatment of cerebral palsy and must be considered for each individual patient. Surgery should be reserved for those contractures that can be effectively released, for those deformities which other measures have failed to correct, and for those patients for whom surgery is a preliminary step for subsequent treatment. Two hundred operations were performed on ninety-five patients during the period from 1948 to 1958. The results were gratifying; muscle function and skill were improved, the need for braces and crutches was eliminated, and the program of therapy was facilitated or shortened.

An Acetabular Prosthesis—Five-Year Follow-up Report. Dr. Earl D. McBride[16] described an acetabular prosthesis and reported on a study made of twenty-three patients who had been followed for from two to five years after insertion of the device. The Vitallium cup, which was designed by the author, has four fins on its convex surface to stabilize the pelvis. A rim, one-quarter of an inch in width, extends outward from the border of the cup and transfers the stress of weight-bearing to the border of the acetabulum. The prosthesis thus relieves the anatomical acetabulum of its function. When the prosthesis is inserted, it is driven into the acetabulum and the reshaped femoral head placed in it. The results to date proved to be satisfactory in protrusio acetabuli, osteo-arthritis, aseptic necrosis of the femoral head, mushroom deformity of the head, and traumatic deformity of the acetabulum.

Intertrochanteric Fractures: Factors Governing the Roentgenographic Prognosis and Complications of Nailing. Dr. Augusto Sarmiento[17] reviewed a large number of operative

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17. Jackson Memorial Hospital, Miami 36, Florida.

procedures in which the Jewett nail had been used for the fixation of intertrochanteric fractures and found that certain positions of the nail led to migration of the nail, or varus deformity of the neck, or both. Adduction of the lower extremity, pull of the adductor muscles of the hip, or both, are determining factors in the production of these complications. The ideal nailing required restoration of the normal valgus position of the femoral neck and placement of the nail, preferably a nail with an angle of 150 degrees, low and posterior in the femoral neck and deep into the femoral head.

Supracondylar Fractures in Children. Dr. William J. Mitchell [18] and Dr. John P. Adams examined eighty-three children with supracondylar fractures of the humerus at intervals of from one to ten years after injury. Sixty per cent of the patients treated by closed manipulation exhibited cubitus varus deformity and moderate limitation of flexion and extension; impending Volkmann's ischemia had developed in three of these patients. Treatment by Dunlop's method of skin traction in a similar series of patients was followed by minimum loss of motion, less cubitus varus, and fewer complications. Comparison of results of various types of treatment including operative reduction, skeletal traction, skin traction, and closed manipulation, disclosed a higher percentage of superior results and fewer complications among the patients treated by skin traction.

Diagnosis and Treatment of Bone Tumors in Children. Dr. Spencer A. Rowland [19], Dr. C. Roger Sullivan, Dr. David C. Dahlin, and Dr. Alvin B. Hayles reported that of 338 primary bone tumors encountered in children at the Mayo Clinic during December 1958, 145 were benign and 193 were malignant. Certain non-neoplastic conditions—such as osteomyelitis—that simulate bone tumor occur more frequently in children than in adults.

The treatment of bone tumors without a histological diagnosis is inexcusable and indefensible. Nor can delay of definitive treatment after biopsy be condoned. If the location of a radioresistant bone tumor of an extremity permits, biopsy should be performed distal to two tourniquets, the histological diagnosis established by a pathologist experienced in the interpretation of freshly frozen sections, and immediate amputation performed between the tourniquets. This regimen seems justified by the author's over-all five-year survival rate of 18.1 per cent after treatment of 106 osteogenic sarcomata (the most common malignant tumor of bone in children). Pessimism as to the prognosis after treatment of malignant bone disease should not be carried to the point that treatment is delayed or postponed because of the misconception that these tumors are inevitably fatal.

The Differential Diagnosis of Isolated Bone Lesions Containing Giant Cells. Dr. James I. Kendrick [20] said that there are a number of bone lesions that contain giant cells, and for some of these a definite diagnosis cannot be made by the pathologist alone. Under these circumstances a precise diagnosis can best be achieved by consultation between the orthopaedist, the roentgenologist, and the pathologist. An accurate diagnosis is important in these lesions if the results of treatment are to be evaluated properly.

Chairman's Address. Motion Picture: One Hundred Years of Arthroplasty of the Knee. Dr. H. Herman Young [21]. During the past 100 years various methods have been tried for reconstruction of the knee joint. These methods included resection, arthrolysis, interposition, and arthroplasty. At best, these procedures gave only a 50 per cent chance for success. The latest method for reconstruction of the knee joint is a hinged prosthesis. As yet, the number of cases reported does not justify any conclusion, but there is reason to believe that satisfactory results may eventually be achieved in 75 per cent of the reconstructions.

Dr. Young's report of his experience in this newest field of replacement arthroplasty—the hinged prosthesis—was not presented as an end-result study and he did not recommend or condemn the procedure. Although only one of the five operations presented could be considered to have had a successful outcome, there were three others that might have been successful had there not been unfortunate complications, none of which was the fault of the prosthesis itself. As yet, the prosthesis is in the developmental stage; time and further experience will determine its value.

The Management of Complicated Ununited Fractures of the Tibia and Fibula. Dr. H. Relton McCarroll [22] reported on a series of thirty-two patients with complicated ununited fractures of the tibia. Nine of these were complicated by overlying scars or soft-tissue defects

18. Washington, D. C.
19. Mayo Clinic, Rochester, Minnesota.
20. 2020 East 93rd Street, Cleveland 6, Ohio.
21. 200 First Street, S.W., Rochester, Minnesota.
22. 3720 Washington Boulevard, St. Louis 8, Missouri.

that necessitated preliminary pedicle skin flaps for adequate skin coverage. In thirty-one of the patients a Phemister bone graft was used, utilizing cortical and cancellous bone. These grafts were placed across the interosseous space, deep to the muscles, in the anterolateral compartment of the leg, an attempt being made to produce, whenever possible, synostosis between the tibia and fibula. The fracture site was drained after operation with one or more Penrose drains left in place for approximately ten days. A massive pressure dressing was used beneath the plaster cast during this period. At the end of ten days the drains and pressure dressings were removed, and a conventional plaster cast was applied. This immobilization was continued until sufficient union of the fracture had occurred to permit weight-bearing with or without a short leg brace. In those patients in whom a short leg brace was used, the brace was worn until bone union was sufficiently solid to permit unprotected weight-bearing. In all thirty-one patients in whom a Phemister bone graft was performed, satisfactory union of the fractures was obtained. In all except two of these fractures there developed sufficient union to permit weight-bearing without support.

It was the author's conclusion that the Phemister bone graft represents a very satisfactory means of treating non-union of fracture of the tibia.

Motion Picture: Surgical Repair of the Ligaments of the Knee and Ankles in Acute Injuries. Dr. Leslie M. Bodnar[23] and Dr. Joseph B. Crowley. This film depicted the types of injury which the authors had observed in football players, particularly those on the Notre Dame team. The film also showed methods of diagnosis and types of treatment. For ligaments detached from bone, such as the internal lateral ligament of the knee joint, a staple countersunk into the bone was used for firm fixation. The film demonstrated the results of these operations by showing football players going through various trick-running maneuvers, jumping, and actually playing football after operation.

The cruciate ligaments were repaired with heavy cotton sutures waxed with bone wax. Although some abnormal mobility after repair could be demonstrated by the so-called drawer sign, on the whole, the results were satisfactory for major contact athletics.

Torn ligaments about the ankle were repaired and the ankle was held in the overcorrected position by a plaster-of-Paris cast. Excellent results were obtained here and were demonstrated by showing the patients competing in athletic contests successfully after the operation.

23. 525 North Michigan Street, South Bend, Indiana.

MID-CENTRAL STATES ORTHOPAEDIC SOCIETY

The Mid-Central States Orthopaedic Society held its Seventh Annual Meeting in Wichita, Kansas, April 7 to 9, 1960. Present at the Annual Meeting of the Board of Directors held on April 7 were: Dr. H. O. Anderson, President, Wichita, Kansas; Dr. Werner P. Jensen, Past-President, Omaha, Nebraska; Dr. Daniel L. Yancey, Vice-President, Springfield, Missouri; Dr. Frank A. Stuart, Tulsa, Oklahoma, and Dr. Oscar P. Hampton, St. Louis, Missouri, both Members-at-Large; and a guest, Dr. William A. Baird, of Ames, Iowa.

The clinical program was held under the direction of Dr. Cline D. Hensley, Wichita, Kansas. A résumé of the papers read follows:

End-Result Studies of Forearm Fractures Reduced with Malalignment in Children. Dr. Ward A. McClanahan[1] presented a series of malunited fractures in children in which a long-term follow-up was available. The children had normal or almost normal function after complete recovery, with restoration of alignment and correction of angulation.

Scoliosis. Dr. William R. Miller[2] discussed the problems confronted in the treatment of scoliosis and advocated the use of the Risser localizer plastic jacket.

Osteotomy of the Spine for Correction of Severe Scoliosis. Case Report. Dr. Lynn O. Litton[3] presented a case report of paralytic scoliosis in which the patient's failure to return for follow-up for several years had resulted in severe scoliosis. An osteotomy of the lumbar spine was carried out at two levels and a magnificent correction achieved.

Treatment of Congenital Pseudarthrosis of the Tibia. A Case Presentation. Dr. M. E. Pusitz[4] presented the case report of a male adult who had had atypical congenital pseudarthrosis of the tibia. The deformity was ultimately corrected after many surgical procedures, including leg-shortening of the normal leg.

Multiple Pin Fixation of Femoral-Neck Fractures. Dr. S. C. McCrae[5] discussed the Austin Moore method of pin fixation for femoral-neck fractures and said that he had found it to be extremely successful.

Traumatic Subtalar Dislocation. Dr. John F. Thurlow[6] described an unusual dislocation after a hunting accident. Immediate reduction and replacement of the foot under the talus resulted in an extremity that functioned unusually well.

Neo-Natal Peroneal Palsy with Case Presentation. Patellectomy with Case Presentation. Dr. Harold S. Bowman[7].

Bone-Stimulation Procedures in Children. Dr. Harry G. Kroll[8] summarized his experience with leg-length stimulation when utilizing the method of Pease. The results obtained were variable.

Heyman Procedure for Adducted Forefeet. Dr. H. O. Marsh[9] utilized the Heyman procedure in seven patients with adduction of the fore part of the foot. Three additional patients were presented for discussion of the possible value of carrying out the procedure in these children.

Amputation in Severe Congenital Deformities of Lower Extremities. Case Presentation. Dr. Cline D. Hensley[10] presented the case of a young boy with severe deformity of both lower extremities. Amputation had been necessary so that the patient could walk and achieve height. An excellent result had been obtained.

The Use of Plaster of Paris to Fill Defects in Bone. Dr. Leonard F. Peltier[11] described

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2. 3244 East Douglas Avenue, Wichita 8, Kansas.
3. University of Kansas Medical Center, Kansas City 12, Kansas.
4. 628 Mills Building, Topeka, Kansas.
5. 519 South Santa Fe, Salina, Kansas.
6. Corner Tenth and Main Streets, Hays, Kansas.
7. 205 K F H Building, Wichita, Kansas.
8. 308 Medical Arts Building, Topeka, Kansas.
9. 3244 East Douglas Avenue, Wichita 8, Kansas.
10. 3244 East Douglas Avenue, Wichita 8, Kansas.
11. University of Kansas Medical Center, Kansas City 12, Kansas.

a method of filling bone defects with pellets of plaster of Paris. Plaster pellets do not promote bone growth or add stability; they are simply a space-occupying material.

The Use of the Split Hansen-Street Nail in Fractures of the Femur—Three Cases. Dr. Charles K. Wier[12] presented three cases where Hansen-Street split nails had been used for fracture of the lower third of the femur with excellent results. The patients demonstrated excellent knee motion and all had excellent gait and strength.

Fractures about the Knee Treated with Internal Fixation with Immediate Mobilization. Dr. Charles Rombold[13] reported on patients with comminuted fractures of the femoral or tibial condyles in whom immediate open reduction had been carried out. The fragments were immobilized with single or double plates and supporting struts. The percentage of good results was gratifying.

The Use of the Bosworth Screw in Acromio-Clavicular Separation. Case Presentation. Resection of the Ulna. Dr. John F. Lance[14] discussed a group of patients whose shoulders had been reconstructed by the Bosworth technique, utilizing the Bosworth screw. Excellent results were obtained.

End Result of Mitchell Procedure for Bunions. Dr. H. O. Anderson[15] said he had used the Mitchell bunion procedure for the last two years and the results had been uniformly good. Cases were presented to illustrate the functional results.

Panel Discussion with Case Presentations. *Moderator:* Dr. Leonard F. Peltier[11]; *Panelists:* Dr. Joseph Gendel[16], Dr. John B. Jarrott[17], and Dr. G. Bernard Joyce[18]. The panel discussed two case reports. The first one was of a man, twenty-five years old, with a fused hip, the result of a surgical procedure for degenerative arthritis. The patient now had a similar degenerative process, with pain and disability, in the opposite hip. The panel was asked what approach they would take for this patient's problem. The second case report was of a patient with recurrent, disabling instantaneous back pain. The general discussion revolved around the various approaches to this problem.

The two-day session closed with a Business Meeting and Second General Session. The officers elected for the 1960–1961 term were:

President: Daniel L. Yancey, M.D., Springfield, Missouri;
Vice-President: Frank A. Stuart, M.D., Tulsa, Oklahoma;
Secretary-Treasurer: H. O. Marsh, M.D., Wichita, Kansas;
Member-at-Large: Hoyt Kirkpatrick, M.D., Fort Smith, Arkansas.

James E. Pollard, M.D., Pueblo, Colorado, and Oscar P. Hampton, M.D., St. Louis, Missouri, will continue to serve as Members-at-Large. W. David Francisco, M.D., Kansas City, Kansas, was appointed Chairman of the Membership Committee.

The 1961 meeting of the Society will be held at the Holiday Inn Motel, Springfield, Missouri, May 4, 5, and 6.

12. 425 North Hillside Avenue, Wichita 8, Kansas.
13. 3244 East Douglas Avenue, Wichita 8, Kansas.
14. 3032 Aloma, Wichita, Kansas.
15. 3244 East Douglas Avenue, Wichita 8, Kansas.
16. 918 West Tenth Street, Kansas City, Kansas.
17. 2415 North Main Street, Hutchinson, Kansas.
18. 308 Medical Arts Building, Topeka, Kansas.

ASSOCIATION OF BONE AND JOINT SURGEONS

As Prepared by William H. Blodgett, M.D., Detroit, Michigan, *Chairman*,
Inter-Association Relationship Committee

The Twelfth Annual Meeting of the Association of Bone and Joint Surgeons was held in Little Rock, Arkansas, March 12 through March 19, 1960, under the Presidency of Dr. Jack Wickstrom, New Orleans, Louisiana. Dr. Harold A. Sofield, Chicago, Illinois, was the honored Guest Speaker, and Dr. Dana M. Street, Little Rock, Arkansas, was the Host and Program Chairman.

Officers elected for the coming year are:

President: Frederick R. Thompson, M.D., New York, N. Y.;

Vice-President: Harry R. Walker, M.D., Oakland, California;

Second Vice-President: William M. Deyerle, M.D., Richmond, Virginia;

Treasurer: Milton C. Cobey, M.D., Washington, D. C.;

Secretary: C. Fred Ferciot, M.D., Lincoln, Nebraska.

The 1961 meeting will be held in Mexico City and Acapulco, with Dr. Guillermo De Velasco Polo as host.

A résumé of each paper presented follows:

The Orthopaedic Surgeon and the Arthritic Patient. Dr. William K. Ishmael [1] said that the management of all but the simplest forms of arthritis is best carried out by a team of physicians representing various specialties. The role of the orthopaedic surgeon is indispensable in most instances, since mechanical factors, which can be controlled by orthopaedic measures, contribute to the pain and fatigue of arthritis.

Dr. Ishmael outlined various procedures for the prevention and treatment of pain and deformity of the spine and peripheral joints, including remedial exercises, braces and splints, traction, plaster casts, manipulation, and surgical treatment. Also considered were systemic therapy with intravenous ACTH and chloroquine and intra-articular therapy with glucocorticoids, nitrogen mustard, pancreatic dornase, and analgesics. The postoperative use of intravenous ACTH and narcosynthesis combined with passive motion was also mentioned. Brief comments were also made concerning the treatment of various related problems, such as bursitis, tenosynovitis, reflex sympathetic dystrophy, and the like.

Experimental and Clinical Lesions Due to Abnormal Mucopolysaccharide Metabolism. Dr. I. V. Ponseti [2] presented a patient with chronic atrophic polychondritis, including drooping ears and very soft nasal and rib cartilages. This disease appears to be due to a metabolic disorder of the chondroitin sulphate similar to the experimental abnormality produced by the administration of papain to experimental animals. The histological lesions in the ear cartilage, the trachea, and the epiphyseal plates of rabbits treated with papain were compared with the lesions of the patient with polychondritis.

Dr. Ponseti presented a boy nine years old, who was one of twins, and a boy ten years old, also a twin, both of whom had a disturbance of endochondral ossification with some of the characteristics observed in Hurler's and Morquio's syndromes. The mentality of the children was normal, and the sella turcica was also normal, as is found in Morquio's disease; however, granules of mucopolysaccharide were observed in the marrow cells of these children. In both diseases there is elimination of a small quantity of an abnormal mucopolysaccharide, which is probably chondroitin sulphate B. Large quantities of chondroitin sulphate B are eliminated by children with Hurler's syndrome. Hurler's syndrome is an inborn error of the metabolism of the chondroitin sulphates with excessive production of chondroitin sulphate B, which accumulates in the liver, spleen, and brain and is the cause of the abnormal endochondral ossification. No abnormal quantities of chondroitin sulphate B have been found in patients with Morquio's disease. The disease of these two patients probably represented a transition form between Morquio's and Hurler's syndromes.

Several patients with Marfan's disease and severe scoliosis and other skeletal deformities and dissecting aneurysm of the aorta were presented. Excessive production of keratosulphate seems to be responsible for the deformities in these patients. Scoliosis and slipped epiphysis can be produced experimentally in vertebrates with the administration of aminonitriles. It is likely that Marfan's syndrome, scoliosis, and slipped epiphysis represent different expressions of an inborn error of the keratosulphate metabolism.

Congenital Dislocation of the Hip. Dr. M. Beckett Howorth [3], in a thesis in 1933, in a paper in 1947, in another paper with W. K. Massie in 1951, and in his discussions at various meet-

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2. University Hospitals, Iowa City, Iowa.
3. 1 Atlantic Street, Stamford, Connecticut.

ings stated that there is no primary dysplasia of the hip in congenital dislocation, that there never was any proof of such primary dysplasia, and that all of the anatomical and pathological and roentgenographic evidence confirmed his concept that the primary factor is a relaxation or elongation of the capsule of the hip joint.

The anatomical evidence includes dissection specimens of fetuses at various ages and of very young infants, as well as pathological specimens and the extensive roentgenographic evidence presented by Massie and Howorth. Confirmatory evidence was found in certain breeds of dogs. Other confirmatory evidence is that all infants with uncomplicated congenital dislocation or subluxation have had general relaxation of the ligaments most noticeable in the knees and feet when the child starts to walk. Finally, if hip subluxation is corrected at an early age, the acetabular deformity disappears, and the acetabulum becomes normal in size and shape. If the subluxation is allowed to persist, the deformity of the acetabulum gradually becomes permanent as the hip develops and ossifies. If the hip is truly dislocated there is little or no deformity of the acetabulum, and even persistent dislocation may result in little deformity, as there is no pressure against the superior acetabular margin. Similarly, if a dislocated hip is completely reduced and the reduction maintained, the acetabulum is normal, but if a dislocation is converted into a subluxation, pressure against the superior acetabular margin will then produce deformity in the growing cartilage of the roof.

Biomechanics and Fixation of Intracapsular Fractures of the Femoral Neck. Dr. William K. Massie [4] stated that intracapsular femoral-neck fractures present unique mechanical problems, accounting for the difficulty in their treatment. It is believed, however, that this fracture, like fractures elsewhere, will heal routinely if all prerequisites for fracture healing can be maintained stringently until healing is complete. The following definitions must be kept in mind:

1. Adequate reduction implies a stable reduction. Frequently, an anatomical reduction is unstable and inadequate, and a valgus position of the head must be obtained.

2. Adequate immobilization implies absolute immobility of the fragment. A single rigid nail rarely fulfills this requirement. Ideally, the appliance should be inserted parallel to the medial trabeculation of the neck and perpendicular to the fracture line, should be collapsible in length to permit further impaction of the fragment, should rest directly on the medial trabeculation to prevent further displacement, and should be firmly fixed laterally to the femoral shaft to prevent wobble or extrusion.

3. Adequate apposition of the fragment implies very firm impaction, requiring many pounds of impacting force, which can be applied by a sharp blow through a suitable instrument to the nailplate junction that is firmly attached to the distal fragment. When the neck then is driven firmly into the head fragment, it will not separate later on.

Obliteration of the fracture line is greatly accelerated; it is often complete in six to eight weeks, and, of more importance, the incidence of avascular change is materially reduced. Revascularization of the head apparently is greatly accelerated because of the rapid healing due to the impaction obtained. Non-union developed in 8 per cent of seventy-four displaced fractures. A technical fault could be demonstrated in each instance. One hundred per cent of the displaced fractures demonstrated avascular necrosis, compared with 12 per cent in the remaining sixty-eight fractures. Only attention to the minute details of the basic principles of fracture treatment can ensure a routinely satisfactory result. Such a good result, however, seems far superior to the best result obtained by prosthetic devices, thus justifying the effort required to treat such a fracture.

Consideration of Hip Disabilities in Children. Dr. Harold A. Sofield [5] discussed disabilities of the hip in children with the subject divided into two general areas. First, the more common causes of disability were considered—namely, congenital dislocation of the hip, subluxation of the hip, Legg-Perthes disease, tuberculosis of the hip, and slipping of the upper capital femoral epiphyses. Second, some of the more unusual disabilities of the hip were discussed—namely, tumors affecting the hip, cysts of the upper end of the femur, ordinary rickets and resistant rickets producing deformities of the upper end of the femur, congenital coxa vara, hip disabilities connected with cleidocranial dysostosis, congenital shortening of the femur, osteogenesis imperfecta deformities affecting the hip, and fractures of the neck of the femur and the intertrochanteric region of the femur in children. Slides were shown illustrating the disabilities in all conditions under discussion, and methods of treatment presently in use were demonstrated by slides and discussed.

Transiliac osteotomy, one of the newer ideas in treatment for congenital dislocation of the hip, was discussed in relation to results obtained from other methods such as the shelf operation, deepening of the acetabulum, and subtrochanteric osteotomy. Various types of fusion for hip disabilities

4. 288 South Limestone Road, Lexington, Kentucky.
5. 715 Lake Street, Oak Park, Illinois.

caused by tuberculosis were shown, and the medical treatment of tuberculosis of the bones and joints was discussed. Pyogenic involvement of the hip seems to be again increasing now that protection from antibiotics is not so effective as formerly. From the operative standpoint, correction of slipping of the upper capital epiphyses still leaves a great deal to be desired. The intra-articular approach with osteotomy across the neck of the femur in old severe neglected cases has not been universally successful.

One of the newer concepts of treatment of hip disabilities, the intentional fracturing by osteotomy of the shaft of the femur repeated at yearly intervals for stimulation of longitudinal growth in cases of congenital shortening of the femur, was discussed. For Perthes disease, the use of a hanging brace with a knee joint, such as has been in use at the Chicago Unit of the Shriners' Hospitals for Crippled Children for twelve years, was also considered. Fragmentation, realignment, and the insertion of an intramedullary rod with correction of coxa vara in patients with marked deformity due to osteogenesis imperfecta were illustrated, as well as the use of fragmentation, realignment, and intramedullary fixation for other conditions, such as the coxa vara associated with resistant rickets.

Open Reduction of Anterior Dislocation of the Hip. Dr. Frederick R. Thompson [6] showed motion pictures of two patients with anterior dislocation of the hip resulting from previous unsuccessful open reduction of congenital dislocation. At the second operation the femoral head lay anterior to the site of the normal acetabulum. The external surface of the ilium was flat, with little or no indentation to indicate the site of an acetabulum.

In one of the hips on which a derotation osteotomy for anteversion had been performed there was no increase in anteversion. The other hip was found to have 90 degrees of anterversion; an osteotomy had not been done at the time of the previous surgery. Neither of the two children had walked prior to the operation for anterior dislocation.

In both instances, after excision of a mass of fibrous tissue representing the scarred capsule covering the site of the acetabulum, a shelf was driven into the flat surface of the ilium to form a superior and anterior roof over the femoral head. A derotation osteotomy was performed on the second patient to correct the marked anteversion. In both patients the femoral heads were held in proper relation to the acetabulum by an intramedullary Kirschner wire that penetrated the femoral neck and the epiphysis into the ilium. The depth of the wire was controlled by the surgeon's fingers within the pelvis. In the first patient a plaster spica was used for eight weeks, and at the end of that time the Kirschner wire was removed and motion was allowed. Postoperative roentgenograms of this patient demonstrated 80 degrees of flexion by the tenth week. The second patient, at the time of the demonstration, was still in plaster.

Anterior transposition of a congenitally dislocated hip was not considered, in the past, as an unfavorable position for the hip. A motion picture of an adult with such a condition was shown to demonstrate that, on the contrary, the anterior position results, at the end of adolescence, in considerable shortening of the leg, a painful deformed hip with limited motion, and a hip that is not improved by an anterior shelf operation. The extensive open operations that were reported on the two infants with anterior dislocation were considered justifiable if the usual outcome of such an anterior transposition of the hip can be prevented.

Tibialis Posticus Transfer for Club-Foot. Dr. Richard M. Logue [7] discussed the technique of anterior transposition of the posterior tibial tendon through the interosseous membrane into the second or third cuneiforms, using four incisions. Dr. Logue believed that the method had the advantage of removing the dynamic deforming effect of the posterior tibial muscle, changing its function into that of a dorsiflexor. He had performed the operation twenty-four times in nineteen patients. He believed that this procedure should not be used in children less than three or four years of age. A number of the patients were presented in whom the operation had been carried out.

A New Technique for Repair of Anterior Cruciate Ligament Tear. Dr. Kenneth G. Jones [8] said that the surgical procedure consists in the formation of a central strip of patellar ligament that is left attached below but freed upward over the anterior surface of the patella into the quadriceps tendon for a distance of one inch above the patella; this forms a continuous strip. The proximal end of this band of tendon is then threaded through a split in the center of the distal patellar ligament into a drill hole in the femur that runs from the posterior aspect of the intercondylar notch posteriorly and laterally to the lateral aspect of the femur.

A patient on whom the procedure had recently been done was presented. Only minimum an-

6. 16 East 90th Street, New York 28, N. Y.
7. 103 East 7th Street, Little Rock, Arkansas.
8. 4300 West Markham, Little Rock, Arkansas.

terior displacement of the tibia on the femur could be demonstrated, but the patient's range of flexion still showed considerable limitation. Dr. Jones expected that further improvement in flexion would occur as active motion continued.

An Abductor Trolley Device to Control Scissor Gait and Tilted Pelvis. Dr. Samuel B. Thompson [9] presented the antiscissoring device that had been devised by Mr. R. T. Hickerson, a brace maker of Little Rock, Arkansas, to control abduction and internal-rotation forces primarily in athetoid or dyskinetic patients with extreme tension in adduction. The device was previously exhibited at the meeting of the American Academy of Cerebral Palsy in 1954, and a report was published in *The Journal of Bone and Joint Surgery* in January 1957. The device consists of a curved slot that is attached to one of the inside uprights that receives a ball-bearing-equipped extension from the opposite inside upright. There is a guard over the top that prevents the separation of the two units. The braces are attached to a semirigid band by means of offset hip joints.

One hundred and sixty of these devices were applied to approximately 100 patients by orthopaedic surgeons in Little Rock. It was found that the device is useful in maintaining adduction of one hip and abduction of another, which appear to have a corrective effect on tilt of the pelvis as it is seen in muscle imbalances above the ilium. Two patients wearing the device were presented.

Unstable Fractures of the Pelvis. Dr. John M. Hundley [10] said that unstable fractures of the pelvis can be recognized by four roentgenograms: anteroposterior, lateral, and anteroposterior views of the patient standing first on one leg and then on the other. Dr. Hundley had had experience with seventy-four fractures of the pelvis. He stated that good reduction could usually be accomplished by applying toe-to-groin plaster cylinders to both limbs and then applying turnbuckles connecting the upper part of the thighs and the ankles. Then, by drawing the plaster cylinders together at the upper part of the thighs and separating the ankle portion, compression on the pelvis could be obtained. The reverse of this maneuver, separation of the upper part of the thighs and drawing the ankles together, causes the hips to separate the pelvic fragments. In eighteen of the patients trisacral fusion was performed.

Experiences with Ostamer. Dr. Paul H. Williams [11] reviewed the literature on ostamer and emphasized that in the methods by which it was applied there were variations in temperature, time and method of mixing, and dryness of the field; there were also differences of opinion with regard to the occurrence of subsequent bone invasion. Dr. Williams had four cases in which ostamer had been used: three pathological fractures consequent to metastasis, and one unicameral bone cyst. Several complications had occurred. No conclusion as to the effectiveness of ostamer was drawn.

Interrupted Short-Wave Therapy (Diapulse). Dr. Dana M. Street [12] reported on the use of diathermy, which is a means of increasing heat in the deep tissues of the body. If a machine is used in which the waves are intermittent, the amount of power necessary is reduced to one-twelfth of that usually used. Because intermittent heat was believed to have unusual healing effects in chronic infections, it was employed experimentally on a severe chronic infection of the hip that had failed to respond after many months of treatment with a number of surgical measures and the entire gamut of antibiotics.

Soon after the treatments with intermittent diathermy were started, reduction of discharge occurred, and there was subsequent complete healing of the sinus tracts. The patient was then presented; there were multiple scars but no open sinuses.

Dr. Street drew no conclusions but stated that he had reported the method as an example of an unusual approach to the treatment of infections and that further investigation in this area would continue.

Letterer-Siwe Disease. Dr. Richard H. Fisher [13] reported on a boy, two years old, in whom multiple lesions of bone had developed. The patient was acutely ill and near death; there were seven lesions involving the long bones, one large lesion of the skull, several lesions of the ribs, and one of the humerus. A biopsy of one of the bone lesions was performed, and a diagnosis of Letterer-Siwe's disease was made. Cultures of the bone lesion and blood revealed a paracolon bacillus of the Arizona group (a gram-negative rod with many characteristics similar to the salmonella group).

9. 103 East 7th Street, Little Rock, Arkansas.
10. 412 Cross Street, Little Rock, Arkansas.
11. 3607 Gaston Avenue, Little Rock, Arkansas.
12. University of Arkansas Medical Center, Little Rock, Arkansas.
13. Lewis-Gale Hospital, Roanoke, Virginia.

The patient, *in extremis*, responded dramatically to heavy doses of antibiotics, including chloromycetin and terramycin, and was alive eight years after the illness.

The author stated that this was a case of Letterer-Siwe's disease in which an etiological agent was established and a favorable response was brought about by antibiotic therapy. It was suggested that exhaustive cultures of the blood and biopsy of the lesions should be carried out in this disease and that this condition may not be invariably fatal, as is recorded in much of the literature. The proof of this interpretation depends on thorough investigation and recording of other similar cases to determine if bacterial organisms can be isolated.

Rate of Fracture Healing in the Aged. Dr. Edgar M. Bick [14] said that the healing rate of fractures in the aged does not differ in time from that of any group of adults. The quality of the reparative bone is similar to that of the bone from which it is derived. Percussion and auscultation to determine the transmission of sound across the fracture site are more valuable in the aged for the determination of the healing of fractures than in younger patients.

The Macrophage Cellular Response to Plastic Substances. Dr. Milton C. Cobey [15] stated that plastics in the proper pH range that contain bone salts become encapsulated in the tissues and evoke a macrophagic response. Under proper conditions a macrophage may show osteoblastic activity.

The microscopic study of a macrophage assumes real importance in work on plastic replacements in the human body. The behavior of a macrophage is the key to the study of tissue tolerance and cellular response. Will the body extrude the plastic by an inflammatory reaction with macrophages and polymorphonuclear leukocytes or will encapsulation be the answer? The labile macrophage changes its morphological characteristics to those of an osteoclast, osteoblast, chondroblast, chondroclast, or other spindle-shaped mesenchymal cell as needed. A macrophage alters itself morphologically and functionally according to the demands placed on it.

Recurrent Dislocation of the Patella. Dr. James B. Jones [16] presented a long-term, follow-up study of patients with recurrent dislocation of the patella treated by transplantation of the tibial tubercle. The records of sixteen patients who had had nineteen recurrent dislocating patellae, all treated by this method, were reviewed. The average time at follow-up examination was 13.3 years. The results were graded as *excellent* in twelve, *good* in six, and *poor* in one knee that had a recurrence of the dislocation. Dr. Jones stated that unless advanced degenerative changes in the patellar articular cartilage have taken place, this reconstructive operative procedure is preferable to patellectomy.

Vertical Talus. Dr. Newton Mead [17] said that although the talus may assume the vertical position in simple congenital flat-foot or in maltreated club-foot deformity, the entity that is understood by the term vertical talus is characterized by the talonavicular dislocation in which the navicular bone is displaced dorsally, thereby locking the talar head in its depressed position and effectively blocking correction of the rocker-bottom foot. Most of these feet are associated with arthrogryposis, spina bifida, or multiple congenital deformities, but the lesion may occur as a solitary deformity.

Severe degrees of this deformity must be corrected by a two-stage operation, similar to that of Hark (1950), for there is inadequate dorsal skin to permit bringing the fore part of the foot down into line with the persistent extreme equinus position of the calcaneus.

The first stage consists in a radical posterior capsulotomy and lengthening of the Achilles tendon, after which the calcaneus is pulled down by a Steinmann pin and retained in plaster for three to six weeks. The second stage, to overcome the dorsiflexion of the fore part of the foot, is accomplished by lengthening or transecting all of the tight dorsal structures, especially the thick capsular ligaments of the talonavicular joint, and levering the navicular bone into proper relation to the talar head; overcorrection of this dislocation is advised. The reduction is maintained by transfixing the reduced joint with a threaded pin or screw. Capsulotomy of the calcaneocuboid joint may be necessary also. The less severely deformed feet may be corrected by a single operation, for a simple lengthening of the Achilles tendon will relax the posterior equinus deformity sufficiently to permit reduction of the mid-tarsal dislocation as just described. Older methods, such as astragalectomy or excision of the talar head, have been unsatisfactory. Even with the method just described, triple arthrodesis may be required when mature bone is present, for relapse often occurs.

14. 30 East 60th Street, New York 22, N. Y.
15. 1726 Eye Street, N.W., Washington, D. C.
16. Suite 8, Medical Center, Lynchburg, Virginia.
17. 636 Church Street, Glenview, Illinois.

Panastragalar Arthrodesis by Compression. Dr. Guillermo De Velasco Polo[18] presented a brief résumé of the use of pantalar arthrodesis as a means of stability in a paralyzed foot. He emphasized the usefulness of compression in children to avoid damage of the epiphyseal line and pseudarthrosis.

The technique described included opening of the ankle joint from the lateral aspect, removal of the articular cartilage from the malleoli, lower tibia, and entire talus, including the taloscaphoid and the calcaneocuboid joints. Compression was accomplished by means of a pin in the tibia above the epiphyseal line and another in the calcaneus. A motion picture showing the technique was presented. Thirty-eight operations by this method were carried out by the author.

18. Zacatecas No. 117, Mexico 7, D. F.

THE RUSSELL A. HIBBS SOCIETY

The Thirteenth Annual Meeting of the Russell A. Hibbs Society was held on March 25 and 26, 1960, at University of Kansas Medical Center, Kansas City, Kansas, with Richard H. Kiene, M.D., presiding. After the Business Meeting, the following new members were elected: James P. Ahstrom, Jr., Mack Clayton, and Fred P. Sage. Dr. Jack Wickstrom was unanimously elected President of the Russell A. Hibbs Society, and Dr. Richard E. King, Secretary-Treasurer. The next meeting of the Society will be held in New Orleans in March 1961.

Summaries of the papers presented follow:

Problem of Refracture in Children with Fracture of Both Bones of the Forearm. Dr. Lynn Litton[1] stated that the German literature listed the incidence of refracture as 6 to 20 per cent. In his series of 128 consecutive cases of fractures of both bones of the forearm in children, there were nine patients with refracture, an incidence of 7 per cent. He divided the cases into two groups: the first group consisted of five patients and refractures within six weeks; the second group consisted of four patients and refractures in from six months to four years. Treatment consisted in always completing the fracture and the use of a long arm cast. It was Dr. Litton's conclusion that eight weeks of immobilization was inadequate.

Laboratory Aids in Diagnosis of Fat Embolism. Dr. Frederico Adler[2] believed that fat embolism is a frequent complication of acute bone trauma and is the leading cause of death after fractures. It also occurs in burns, severe infections, alcoholism, poisoning, and simulated high-altitude flights, and after total body perfusions. Clinically, the diagnosis is usually made too late or not at all. For prognostic and therapeutic reasons, laboratory diagnosis becomes pre-eminent. Essentially, fat embolism consists in two phases: (1) a mechanical phase of acute mechanical embolization of non-physiological fat droplets into the circulation with obstruction of the pulmonary capillary bed and subsequent failure of the right side of the heart, and (2) a chemical phase of hydrolysis of embolized fat by pulmonary parenchyma. During the mechanical phase, circulating fat droplets can be detected in the blood by the method of Gohrbandt, utilizing Nile-blue sulphate, or the method of Peltier, using phosphin 3R. The incidence of lipuria during this phase is high and can easily be detected microscopically or macroscopically by methods standardized by Dr. Adler's group utilizing Sudan III and Nile blue, respectively. Laboratory evidence of the second phase is found through the determination of the serum lipase level. Dr. Adler's group studied forty patients with intertrochanteric fractures and multiple injuries to the soft tissues and skeleton, correlating the incidence of lipuria and the elevation of the serum lipase levels. Lipuria was present in 57.5 per cent of all patients, and an elevated serum lipase level was present in 52.5 per cent. Lipuria occurred early, and the elevation of the serum lipase occurred somewhat later. Of the patients studied, 76.5 per cent exhibited lipuria during the first four days after injury, and 75 per cent showed elevated serum lipase levels after the fourth day. It was concluded that the detection of lipuria constitutes an adequate laboratory test for the mechanical phase of fat embolism, and the determination of serum lipase is an adequate test for the chemical phase.

1. University of Kansas Medical Center, Kansas City 12, Kansas.
2. University of Kansas Medical Center, Kansas City 12, Kansas.

Philip Syng Physick's Case of an Ununited Fracture of the Humerus Cured by the Use of a Seton. Mr. George F. Sheldon [3] reported on the follow-up, twenty-eight years later, of this fracture that was operated on in December 1802. The procedure consisted in passing a seton between the unopposed fragments of the humerus and placing traction on the extremity. The seton was then passed out the opposing side of the arm, and a piece of suture was left in the region between the unopposed ends of the bone. Approximately two years after the accident, the patient was dismissed from Pennsylvania Hospital, with, in his own words, his "arm as strong as before".

The Use of Plaster of Paris to Fill Defects in Bone. Dr. Leonard F. Peltier [4] mentioned that plaster of Paris has been used to fill defects in bone since 1892. There have been numerous reports of the clinical use of this material in the foreign medical journals. Extensive animal experimentation in Dr. Peltier's laboratory has shown that: (1) the presence of plaster of Paris within the bone or soft tissue does not provoke a foreign-body reaction; (2) plaster of Paris is rapidly resorbed from the site of implantation; (3) the presence of plaster of Paris in no way inhibits the normal growth and repair of bone; (4) plaster of Paris provides no mechanical support; and (5) plaster of Paris does not stimulate osteogenesis. The clinical experience of Dr. Peltier's group now includes cavities in the bone associated with the excision of benign and malignant tumors, bone cysts, traumatic defects, and osteomyelitis. In no case has the use of plaster of Paris proved harmful. In most cases the defects have promptly filled in with normal bone.

Tibial Plateau Fractures. Dr. John L. Barnard [5] presented a series of tibial-plateau fractures that were treated in several hospitals in Kansas City during the past ten years and were reviewed in an attempt to correlate the method of treatment with final functional results. Luck's classification of plateau fractures was used. Only those fractures that had central depression of the joint surface of more than one centimeter were treated by open reduction. The remainder of the fractures were treated by early motion, using Buck's extension and delayed weight-bearing for three to four months. A comparison of roentgenograms, review of the cases treated more than ten years ago by other methods, and evaluation of the functional results led to two conclusions: (1) there is no definite correlation, within reasonable limits, between anatomical appearance of the fracture on the roentgenogram and the final functional result; and (2) early motion appeared essential.

Abstract of Case Presentation. Dr. Herbert A. Hamel [6] reported that a Caucasian man, fifty-eight years old, sustained an open, segmental fracture of the right humerus, which was treated primarily by irrigation, débridement, closure of the wound, and a hanging cast. After ten weeks the proximal fracture healed, but the distal fracture showed delayed union; the original wound was still open, with the bone exposed. The adherent scar around the wound and the exposed spicule of humerus were excised. Immobilization in plaster was continued for three additional months, but frank non-union developed. An onlay graft with iliac bone was attempted, but the graft fractured during application, and a Lane plate was applied with grafts placed about the fracture. Two days after operation there was complete radial-nerve palsy. The wound was reopened, and the radial nerve was explored and stimulated; all branches of the nerve were found to be intact. The patient was discharged from the hospital but returned two days later with paresthesiae and generalized weakness in the lower extremities that progressed to complete paralysis of both upper and lower extremities. A lumbar puncture revealed a spinal-fluid protein of 88 milligrams per 100 milliliters and a cell count of 100, mostly red cells. The final diagnosis was Guillain-Barré syndrome. Complete recovery of muscle power followed, including recovery of the radial-nerve function on the right, but the paresthesiae in the extremities continued. Union of the fracture of the humerus did not take place, and another bone-graft operation was performed elsewhere.

Morton's Toe or Morton's Foot. Dr. Garrett Pipkin [7] analyzed forty consecutive histologically proved interdigital neuromata of the foot (Morton's toe). Seventeen of the forty neuromata occurred in the web between the second and third toes. All these feet had the configuration of Morton's foot (short first metatarsal). This clinical experience is in contrast with the usual textbook dictum that neuromata are most common in the web between the fourth and fifth toes.

3. Junior Medical Student, University of Kansas School of Medicine, Kansas City 12, Kansas.
4. University of Kansas Medical Center, Kansas City 12, Kansas.
5. Dickson-Diveley Clinic, 4312 J. C. Nichols Parkway, Kansas City 11, Missouri.
6. 6303 Morningside Drive, Kansas City 13, Missouri.
7. 409 Argyle Building, Kansas City 6, Missouri.

The Industrial Back. Dr. Robert M. Drisko [8] reported a survey of seventy-four consecutive patients hospitalized with back injuries due to industrial accidents. The study extended over a period of ten years. All patients worked for a large Western railroad in various occupations. Most of the patients were referred to the hospital with a diagnosis of herniation of an intervertebral disc. The distribution of patients was equal among the age groups of thirty to forty, forty to fifty, and fifty to sixty years, but there were also a few younger and a few older patients. Laborers engaged in occupations requiring daily heavy physical exertion had the lowest incidence of injury, whereas those engaged in occupations requiring occasional heavy physical exertion had the highest incidence of injury. Among the seventy-four patients studied, the onset of symptoms was associated with on-duty injuries in twenty-one, with off-duty injuries in seven, and with no history of injury in forty-six patients. Myelograms were performed on sixty-four patients, and operations were performed on fifty-seven of the seventy-four patients. The myelographic findings agreed with the surgical findings in 81 per cent of the cases. The distribution of discs involved was about equal between the lower two lumbar interspaces. There were forty-seven discs excised and fifteen spine fusions. One pseudarthrosis was diagnosed; all patients had flexion, extension, and lateral-bend roentgenograms. Spine fusions were not performed on any of the patients with disc herniations at the interspace between the fourth and fifth lumbar vertebrae. All the fusions were performed at the lumbosacral interspace. This procedure was adopted because it was thought that herniation at the fourth lumbar interspace did not need fusion and also because of the high incidence of pseudarthrosis at this level. All operations were performed by one surgeon. For the fifty-seven patients operated on, the average total hospital stay was 17.4 days, and the average postoperation hospital stay was 10.8 days. Forty-nine of the fifty-seven patients returned to work within an average of eighty-eight days; the other eight patients did not return to work for various reasons. One patient was a pensioner, another had a severe arm injury, and two had other illnesses; no follow-up was available for two other patients. Few claims were filed, and no cases were taken to court. Dr. Drisko believed that this survey showed that end results fairly comparable with those in private practice can be achieved in industry if there is good cooperation from the patient and the safety, the personnel, and, particularly, the claims departments.

Tuberculous Spondylitis in Adults. Dr. Donald D. Hobbs [9] stated that in 1915 Russell A. Hibbs reported on 210 patients with tuberculous spondylitis treated by posterior-element fusion; 75 per cent of the operations resulted in cures, 11 per cent were failures, and 14 per cent resulted in death. In 1954, Hallock and Jones reported a follow-up study of 192 patients similarly treated at the New York Orthopaedic Hospital; the disease was arrested in 74 per cent, 7 per cent of the operations were failures, and 19 per cent of the operations resulted in death. The deaths in both series were caused by systemic tuberculosis; the respiratory, renal, and meningeal systems were most commonly involved. The antituberculosis bacteriostatic drugs are adjuncts in the treatment of tuberculous spondylitis, and use of these drugs allows earlier surgery, earlier mobilization, and improved healing of soft-tissue lesions; the drugs also help control generalized infection. The commonly used medications are various combinations of streptomycin, isonicotinic and ipronicotinic acid, and para-aminosalicylic acid. It is generally agreed that these drugs should be continued for at least six months after all signs of activity of the disease, as evidenced by roentgenographic examination, have subsided. Seven patients with tuberculous spondylitis treated at the Kansas City Veterans Administration Hospital from 1951 to 1960 were reported on. The average age of these patients was fifty years. They had been treated by rest and antituberculosis medications for periods of six to eight weeks prior to posterior spine fusion. All were supported in a plaster body jacket or Taylor back brace for six to eight months after operation. Medications were generally continued for a total of twenty-four months. In the group treated, one death occurred as a result of cerebral thrombosis in a patient in whom there developed paraplegia caused by an intraspinal tuberculous granuloma without roentgenographic evidence of osseous involvement. The incidence of advanced age and the lack of progression of the systemic disease in these patients were discussed.

Chronic Infectious Lesions of Bone. Dr. Otis B. James, Jr. [10], reported on three interesting cases that presented diagnostic problems caused by chronic inflammatory reactions in bones. Two of the patients were children whose lesions strongly resembled neoplastic conditions. All patients had similar histories of no previous injury and no known illness or local infection. The principal findings in all patients were local pain and soft-tissue swelling of variable degree. In both children the roentgenographic changes were predominantly laminated periosteal reactions, whereas in the adult there was a typical osteolytic reaction with subsequent signs of a healing reaction that

8. 4620 J. C. Nichols Parkway, Kansas City 12, Missouri.
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involved the distal two-thirds of the right radius. The interval between onset of symptoms and roentgenographic changes varied from three weeks to three months. Laboratory studies were essentially negative except for signs of inflammation. Both children underwent surgical biopsy. One lesion was in the upper femoral shaft; the other involved the upper tibial shaft. Blood cultures and cultures from the bone lesions were negative. Pathological reports were that there was chronic osteomyelitis in both instances. Treatment was primarily immobilization with adequate antibiotic therapy. All patients made satisfactory and uneventful recoveries. It has been suggested that this type of reaction in osteomyelitis in children is due to a salmonella organism. Similar cases have been reported previously.

Case Presentation. Dr. Richard A. Gruendel [11] presented the case of a farmer, forty-nine years old, who was injured when his tractor overturned, pinning him to the ground. He was initially treated for shock at a community hospital. On the tenth day, he was transferred to the Kansas City Veterans Administration Hospital for orthopaedic treatment. Lateral roentgenograms of the lumbar area showed forward dislocation of the fourth lumbar vertebra, its body being displaced anterior to that of the fifth lumbar vertebra about 50 per cent of the width. A fragment of the anterior portion of the body of the fifth lumbar vertebra lay in normal relationship to the anterior margin of the body of the fourth. The fifth lumbar vertebra was posteriorly dislocated upon the sacrum approximately one-fourth of its anteroposterior diameter. The inferior articular process of the fourth lumbar vertebra appeared to be impacted into the body of the fifth. The spinous processes of the first four lumbar vertebrae were fractured, as were the transverse processes of the second, third, and fourth lumbar vertebrae. Despite this marked disruption of the normal relationship of the vertebral column, no neurological deficit could be detected. The patient was first placed in straight pelvic traction, and weights up to seventy pounds were applied without any visible change in the position of the fractures. Hyperextension of the spine was also tried without improvement of the deformity. Five weeks after the injury, a pantaloon body cast extending to the knees was applied. The cast was worn for seven weeks. Gradual mobilization with the aid of crutches was then started with the support of a chair-back type of back brace. The patient was discharged from the hospital fifteen weeks after the injury. The neurological status remained normal; the patient's only complaint was of an easy fatigability of the low back. The last roentgenographic examination showed evidence of callus formation and anterior interbody fusion of the dislocated bodies.

Lesion in the Left Tibia. Dr. Phil A. Webb [12] reported the case of a married Caucasian woman, twenty-four years old, with a lesion in the left tibia known to have been present for five years. The chief complaint of the patient was of an aching discomfort in the mid-portion of the left leg after exercise. Physical examination revealed some anterior bowing of the left tibia and a definite thickening of the shaft of the tibia. Roentgenograms of the lesion made when the patient was nineteen, twenty-two, and twenty-four years of age were presented. The last ones were made when she was first seen at the Dickson-Diveley Clinic. Histological sections were also presented that showed a thickening of the trabeculae and the typical mosaic pattern of Paget's disease.

Harrington Instrumentation of the Spine for Correction of Scoliosis. Dr. Paul W. Meyer [13] described Harrington's method for the treatment of scoliosis that involves the correction of scoliosis by internal metallic fixation, using distraction and compression forces applied to the axial skeleton. The distraction force is always applied to the concave side of the curve, whereas the compression force is always applied to the convex side of the curve. The forces of compression and distraction are applied by means of a metallic rod with a rachet device for the adjustment of the length and hooks that are applied usually to the transverse processes or laminae of the vertebrae as close to the articular facets as possible. One of the advantages of this metallic internal fixation is its demonstrated efficiency in the correction of scoliosis in the severely handicapped child with decreased cardiorespiratory and decreased musculoskeletal functions. The method also has the advantage that it avoids prolonged immobilization, casts, and pressure sores, and simplifies nursing and reduces hospitalization. Some of the disadvantages encountered include the need for reoperation to adjust the strut, fractures of the device, and erosion of bone. This new approach in the treatment of scoliosis offers the orthopaedic surgeon food for thought in treating this problem.

The Use of Fascial Transplants. Dr. Richard H. Kiene [14] stated that the purpose of fascial

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transplants is: (1) to recapture muscle pull as far as possible so that a deforming force may be balanced, or impaired function may be improved; (2) to improve the stability of the spine by making more effective use of available forces to gain correction in paralytic scoliosis; and (3) to improve gait and endurance in walking by improving the balance of the trunk of the pelvis. To demonstrate the purpose of fascial transplants three general classes of transplants were shown in patients: (1) abdominal transplants used to balance deforming forces by recapturing lost muscle pull; (2) fascial transplants from the scapula to the cervical muscles to add stability to the pectoral girdle in high thoracic paralytic scoliosis, thus enabling better correction to be obtained; and (3) transplants from the greater trochanter to the sacrospinalis muscles to improve balance of the trunk on the pelvis. Each fascial transplant is an individual problem, and repeated examinations of the patient at rest, standing, walking, and sitting are necessary before such procedures should be carried out. The Beevor sign is very useful in determining the paralysis of the abdominal muscles. The maneuver of simulating the function of the fascial transplant with the hand will give an indication of the results that may be obtained. In the operative technique the fascia should be placed in a straight line from the active muscle to the bone and fixed first into the muscle and then under tension in the bone. Patients were presented to illustrate all points discussed and to show end results.

African Safari with Comments on Medical Affairs. Dr. Rex L. Diveley [15] took the Russell A. Hibbs Society on a delightful guided tour of Africa by means of colored slides combined with sound.

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News Notes

On October 5, 1960, a plane crashed while taking off from Logan Airport, Boston, Massachusetts. In this tragic accident, David S. Grice, Professor of Orthopaedic Surgery at The University of Pennsylvania, died at the age of forty-six. The Journal makes this announcement with a sense of great loss—loss of a bright and rising star on the orthopaedic horizon, loss of one of our ablest and most faithful associate editors, and loss of a dear and devoted friend. The Board of Associate Editors and the Staff at 8 The Fenway extend to Mrs. Grice and the three children their deepest sympathy.

The Twenty-eighth Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Americana, Bal Harbour, Miami Beach, Florida, from January 8 through January 13, 1961.

The Sixteenth Annual Meeting of the **American Society for Surgery of the Hand** will be held on Friday and Saturday, January 6 and 7, 1961, at the Hotel Americana, Bal Harbour, Miami Beach, Florida. The preliminary program follows:

Friday, January 6

A Quantitative Study of the Vascular Beds of the Hand: James B. Wray, M.D., Winston-Salem, and J. E. Markee, Durham, North Carolina;

Repair of Atomic, Cathode, Cyclotron, and X-Ray Burns of the Hand: Long-Term Follow-up with Microscopic Studies: Minot P. Fryer, M.D., and James B. Brown, M.D., St. Louis, Missouri;

Electrical Injury to the Hand: Clifford C. Snyder, M.D., Miami, Florida;

Injury of the Median and Ulnar Nerves, 150 Cases, with an Evaluation of Moberg's Ninhydrin Test: William B. Stromberg, Jr., M.D., Robert M. McFarlane, M.D., John L. Bell, M.D., Michael L. Mason, M.D., and Sumner L. Koch, M.D., Chicago, Illinois;

A Long-Term Follow-up Study of 180 Cases of Civilian Peripheral Nerve Injuries: Harilaos Sakellarides, M.D., Boston, Massachusetts;

Presidential Address—Congenital Absence of the Ulna: Daniel C. Riordan, M.D., New Orleans, Louisiana;

Use of Synergistic Transfers in Spastic and Paralytic Hands: Mark H. Greene, M.D., Salt Lake City, Utah;

Transfer of the Extensors of the Wrist and Digits to Restore Opposition of the Thumb: Edward D. Henderson, M.D., Rochester, Minnesota;

Guest Speaker: Paul Brand, M.D., India;

Indications for Prosthetic Replacement for Rheumatoid Finger Joints: Adrian E. Flatt, M.D., Iowa City, Iowa;

Fractures of the Hand: W. D. Butt, M.D., St. Catherines, Ontario, Canada;

The History of Flexor-Tendon Grafting: Jerome E. Adamson, M.D., Norfolk, Virginia, Joseph H. Boyes, M.D., and James N. Wilson, M.D., Los Angeles, California.

Saturday, January 7

Rhabdomyosarcoma of the Hand: Austin D. Potenza, Capt. (M. C.), and Donald J. Winslow, Lt. Col. (M. C.), Washington, D. C.;

Reconstruction of the Thumb: J. Edward Flynn, M.D., Boston, Massachusetts;

Wringer Injuries of the Hand: Vinton E. Siler, M.D., Cincinnati, Ohio;

An Experimental Evaluation of the Efficacy of Chymotrypsin in the Reduction of Edema in Crushed Extremities: Robert D. Allaben, M.D., Robert D. Larsen, M.D., and Joseph L. Posch, M.D., Detroit, Michigan;

Gout in the Upper Extremity and Hand: Lee R. Straub, M.D., and J. James Smith, M.D., New York, N. Y.;

Primary and Secondary Reconstruction of Finger-Tip Injuries: Richard I. Gonzalez, M.D., and Harry J. Buncke, Jr., M.D., San Mateo, California.

A review course on Fractures for those qualified is offered on the non-operative and operative treatment of fractures of the spine and extremities. Instruction will include basic anatomical background in the treatment of fractures, including demonstrations by anatomical specimens to illustrate the principles of bone and joint deformities after fracture, neurovascular dangers, loca-

tion of sites for skeletal traction, and anatomical approaches to the bones and joints. The program will be under the direction of **Dr. Carl E. Badgley,** assisted by his staff in the Division of Orthopaedic Surgery, and by members of the staffs in other surgical specialties. It is to be held at the University of Michigan Medical Center, Ann Arbor, Michigan, November 10 and 11, 1960.

The **Exchange Fellowship Committee of The American Orthopaedic Association** is now inviting applications from American orthopaedic surgeons who are interested in the tour to Great Britain in the Spring of 1961. The requirements are: The applicant must be under forty years of age as of December 1, 1960; he must have completed Part II of the American Board of Orthopaedic Surgery examinations; and he must be a citizen of the United States. Requests for application blanks should be made to the Chairman of the Exchange Fellowship Committee, Dr. J. Neill Garber, 806 Hume Mansur Building, Indianapolis, Indiana.

The **American Academy for Cerebral Palsy** held its Thirteenth Annual Meeting in Pittsburgh, Pennsylvania, October 5 through 7, 1960. Dr. G. W. N. Eggers, Galveston, Texas, is the President for 1960–1961. The other officers elected are:

President-Elect: Jessie Wright, M.D., Pittsburgh, Pennsylvania;
Vice-President: Russell Meyers, M.D., Iowa City, Iowa;
Secretary: J. D. Russ, M.D., New Orleans, Louisiana;
Treasurer: Samuel B. Thompson, M.D., Little Rock, Arkansas.

The 1961 Annual Meeting will be held in St. Louis, Missouri, on November 9–11.

The Part II examination for Certification by the **American Board of Orthopaedic Surgery** will be held January 4 through 6, 1961, at the Americana Hotel, Bal Harbour, Miami Beach, Florida. Sam W. Banks, M.D., *Secretary,* 116 South Michigan Avenue, Chicago 3, Illinois. (Final date for filing application **was** July 1, 1960.)

The Part I examination for Certification by the **American Board of Orthopaedic Surgery** will be held in Palo Alto, California; Nashville, Tennessee; and Philadelphia, Pennsylvania, June 19–20, 1961. (Final date for filing application is January 1, 1961.) Sam W. Banks, M.D., *Secretary,* 116 South Michigan Avenue, Chicago 3, Illinois.

A letter from **Yasukazu Abe,** author of Thirteen Cases of Alkaptonuria from One Family Tree with Special Reference to Osteo-Arthrosis Alkaptonurica (The Journal, 42-A: 817–831, July 1960), informs us that he gave the wrong name to one of his co-authors. Ryoshin Hatanaka should be changed to **Yoshiomi Hanakita.**

Book Reviews

Re-education of the Injured Shoulder. R. Barrie Brookes, F.C.S.P. Edinburgh and London, E. and S. Livingstone, Ltd., 1958; Baltimore, The Williams and Wilkins Co., 1959. $3.50.

This is a very readable, concise treatise on the rehabilitation of the injured shoulder presented in eleven chapters and 111 pages. The reader is readily impressed by the fact that the author is an able and perceptive physical therapist, associated with a large, active, well organized hospital clinic.

The discussion of each problem of the shoulder is preceded by a review of essential anatomy and relevant physiological and mechanical factors. It is encouraging to see the omission of many routine exercises, which have, in the past, served to irritate and aggravate, rather than to help the patient. The author's guiding principle, from a study of 779 patients, is "the necessity for movement [of the shoulder] at the earliest possible moment". One of the more significant contributions of this book is that it tells the reader how to accomplish this early movement painlessly and with good physiological effect.

Heat is used in moderation. Perhaps more emphasis could have been given the application of moist heat, but the obvious omission of many popular forms of heat waves and sound waves today is to be commended.

The section on lesions of the rotator cuff is well presented, with logical suggestions and treatment. The section on dislocations of the shoulder also indicates acute observations by the author and good follow-up study.

The book could be improved by better photography and sketching to illustrate the author's many good suggestions. It is unfortunate that the publishers permitted pages 37 and 43 to be repeated in the text.

Those persons who see many shoulder problems will definitely profit by reading Mr. Brookes' book.

Carter R. Rowe, M.D.

Fundamental Techniques of Plastic Surgery and Their Surgical Applications. Ian A. McGregor. With a Foreword by C. F. W. Illingworth. Edinburgh and London, E. and S. Livingstone, Ltd., 1959. 30s; Baltimore, The Williams and Wilkins Co., 1960. $7.00.

For those who, like this reviewer, spend much of their professional lives teaching interns, residents, and others, this little volume will come as a very welcome addition. The author comments in his preface: "Plastic surgical methods are being used increasingly often by surgeons who have received no formal training in plastic surgery and who are looking for guidance on the basic techniques". Where many textbooks of plastic surgery fail is in "giving enough details of actual technique to be of practical use". McGregor succeeds admirably in his desire to fill the gap.

More than half of the 235 pages are devoted to a review of basic techniques, including wound care, skin grafts, and methods of flap preparation and transfer. Among other practical matters discussed are factors influencing the taking of a graft, preparation of a granulating surface for grafting, care of the donor area, and the Z-plasty. Several antibiotic, enzymatic, and chemical debriding agents and the effect of antibiotics on the local wound are discussed, but McGregor's concluding sentence is most timely: "A meticulous dressing technique . . . provides a better insurance against superadded infection than a blind reliance on antibiotics".

In the second part, surgical applications of these techniques to general, orthopaedic, hand, and eyelid surgery are described. Many of the pitfalls that the teacher of plastic surgical principles must convey to his preceptees are well described and illustrated. However, as is often true of any description of techniques and principles, the uninitiated who has not encountered a complication may, because of his limited experience, fail to grasp the importance of each detail. The author has cited these pitfalls and complications and indicated with great care how they can be avoided. Whether the reader of this excellent volume will catch the significance of the many important precautions is uncertain—the admonitions are there.

For the surgeon who asks: "What tricks are there in doing this or that?" almost all the answers will be found, not recorded as tricks but recorded as very suitable, well illustrated, and well selected methods familiar to any properly trained plastic surgeon.

Bradford Cannon, M.D.

Postural Fitness. Significance and Variances. Charles LeRoy Lowman, M.D., Sc.D., F.A.C.S., and Carl Haven Young, Ed.D., C.C.T., F.A.A.P.M.R. Philadelphia, Lea and Febiger, 1960. $7.50.

This presentation by Dr. Lowman and Dr. Young is stimulating; it is a marvelous source of information for educators as well as for persons in all branches of medicine. The authors emphasize

the necessity for a program of physical fitness and describe in an admirable manner normal and abnormal physical fitness and the treatment of those abnormalities that may be corrected by physical-fitness programs. The authors place the responsibility for the management of the physical fitness of the youth of the country on society in general. Hence, physical fitness is the responsibility of all persons engaged in social-service endeavors; it is, of course, the responsibility of the medical profession. Sufficient statistical material is presented to emphasize the necessity for a physical-fitness program in our schools to be a public responsibility.

The physiology of the locomotor system is covered, and the relation of the locomotor system to the function of other organs of the body is explained. Deviations from normal and the individual variations that fall within the realm of normalcy are well presented. A method for the analysis and quick review of physical fitness is presented, which consists in the study of each person from two planes—namely, from the lateral as well as the anterior and posterior planes. The authors recognize the importance of rapid examination when dealing with large groups of persons, and methods for such rapid examination are described.

The physiological explanation for the advantages of exercises is explained in a very convincing manner, and the methods for the correction of abnormalities are well presented. The types of exercises to be carried out in different age groups to obtain the desired results from physical education are completely reviewed.

This is a beautifully prepared book. The text is full of provocative similies and metaphors that enhance its readability and stimulate the reader. Physical educationalists can derive much information from this masterful presentation with its extensive and all-inclusive bibliography. This book should be considered as a marvelous reference for all people concerned with locomotion, as well as for educators who are concerned in any manner with physical-education activities.

Joe B. Davis, M.D.

Biomechanics of the Central Nervous System. Some Basic Normal and Pathologic Phenomena. Alf Breig. Chicago, The Year Book Publishers, Inc., 1960. $8.50.

What happens to the spinal cord and hindbrain under the conditions of mechanical stress caused by changes in position has never been systematically studied. Little, if anything, was known of the changes that occur in the cord, the nerve roots, and the supporting apparatus, including the covering membranes, during extension, flexion, or rotation of the vertebral column. The need for such knowledge was always present but, surprisingly enough, no one has investigated this matter.

The author of this monograph deserves credit for the excellent study of the problem. It is a valuable contribution, original in its conception and fruitful in its results. It is based on observations on 143 cadavera that were submitted to mechanical stress and experimentations; it was supplemented by roentgenographic examination on living subjects submitted to maximum functional positions. Air myelography, angiography, encephalography, and observations during surgical operations were all used to make the study as complete as possible.

The method of investigation on cadavera is described in detail, and the changes observed under these experimental conditions are presented in a precise and convincing fashion. Some of the results obtained during surgical operations and in these experiments indicate that some of the traditional views on the tension developed in the cord in different positions will require considerable revision.

The monograph has only 183 pages and is illustrated with 109 figures. The reproductions of the roentgenograms, photographs, and microphotographs illustrate superbly the changes in the nervous system and the structures of the spine. The line drawings are equally excellent. Anyone interested in the physiomechanics of the spine or in functional anatomy of the vertebral column from the viewpoint of surgical interference or interpretation of normal and pathological manifestations has to acquire the information provided by the present investigation.

Emanuel B. Kaplan, M.D.

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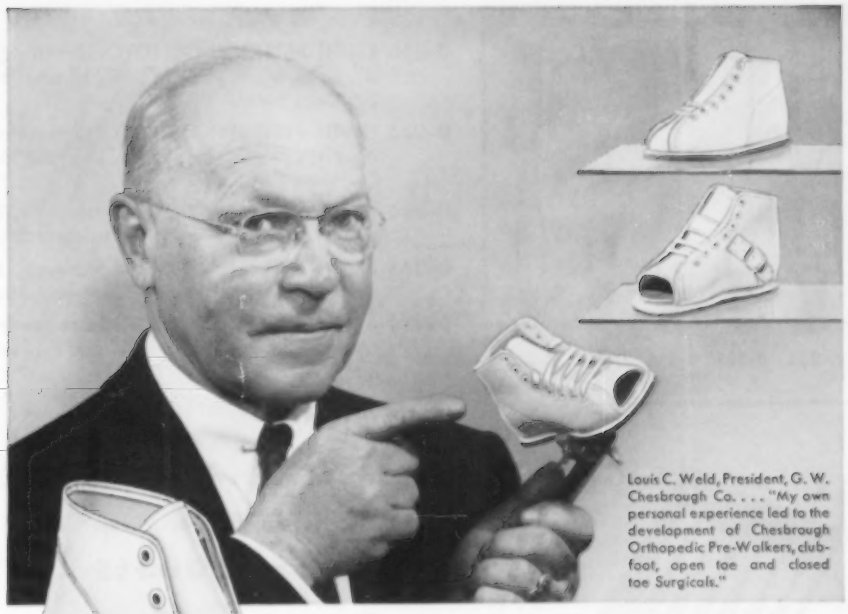

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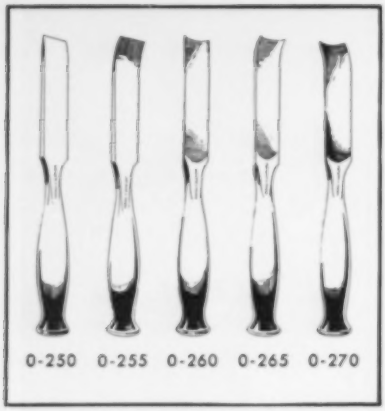

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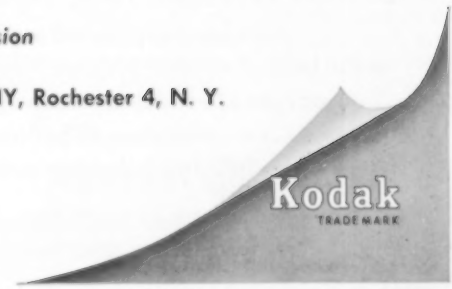

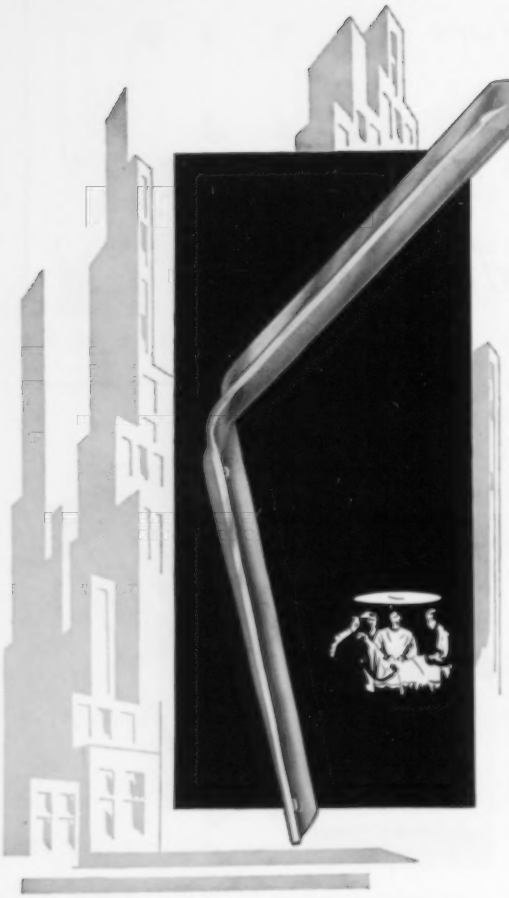

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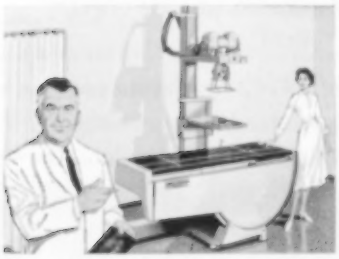

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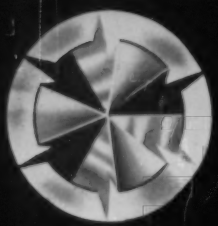

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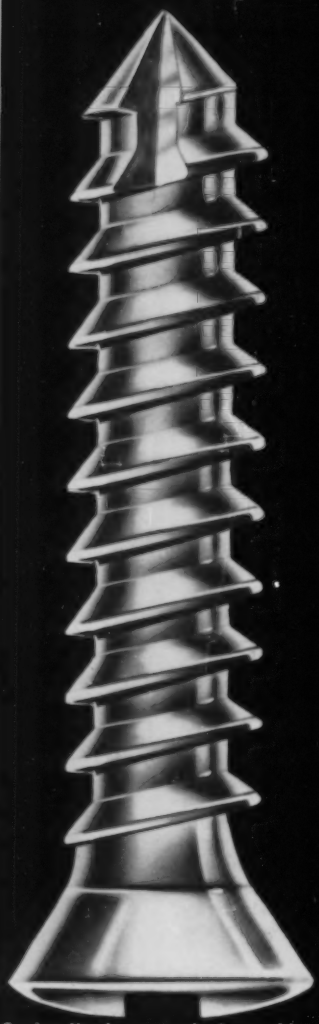

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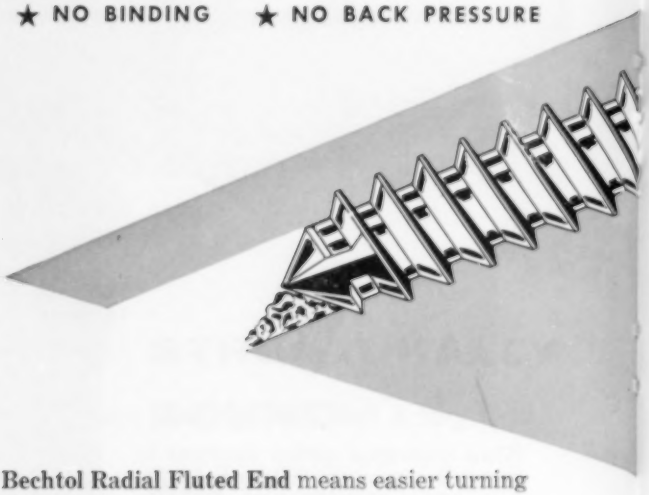

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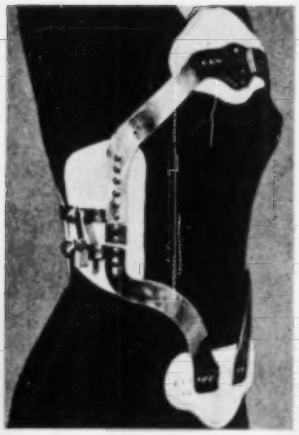

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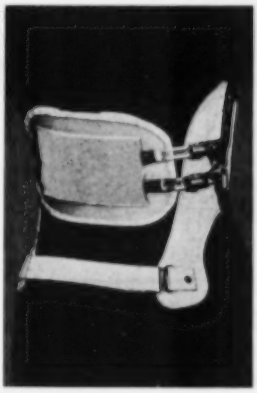

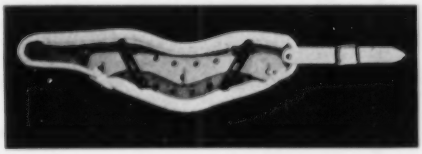

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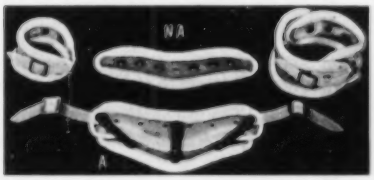

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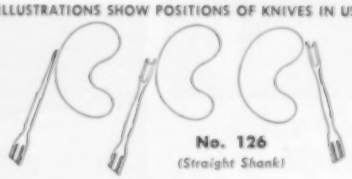

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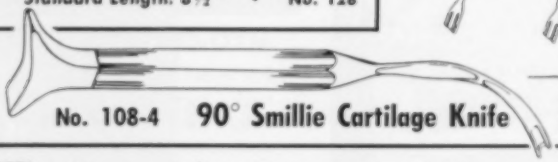

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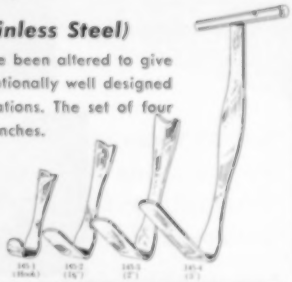

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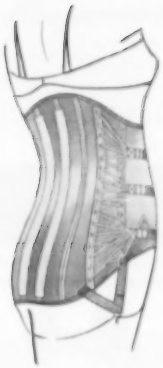

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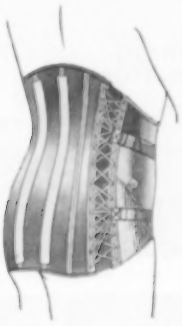

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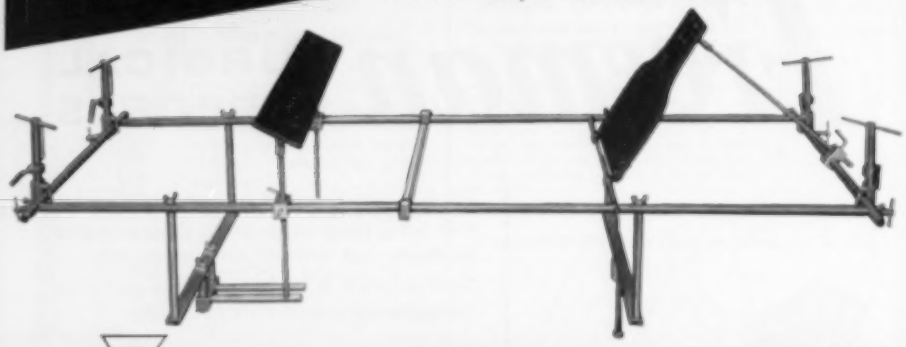

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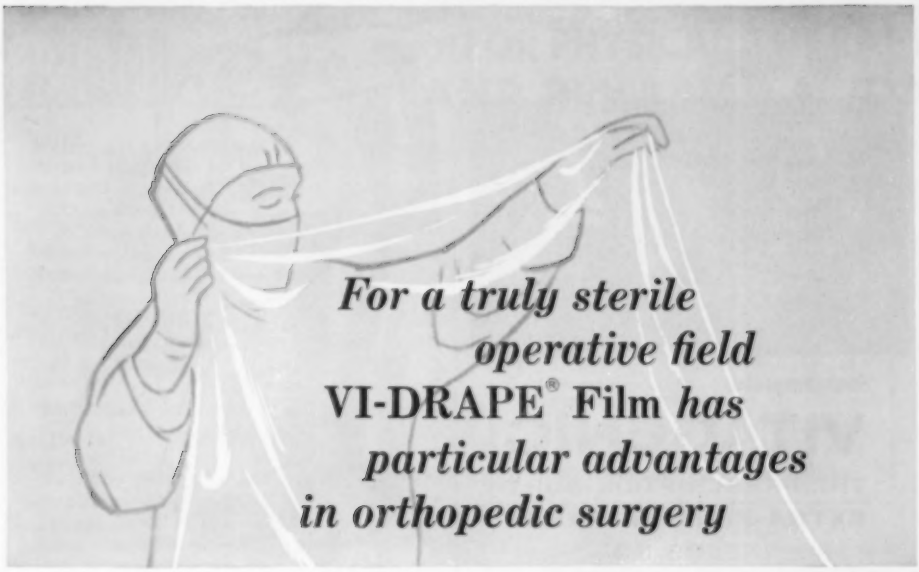

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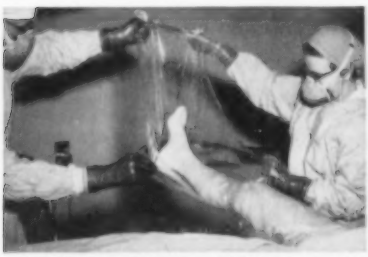

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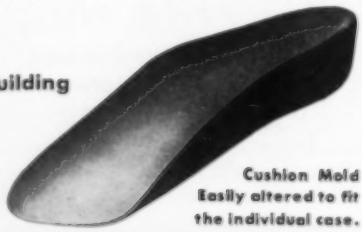

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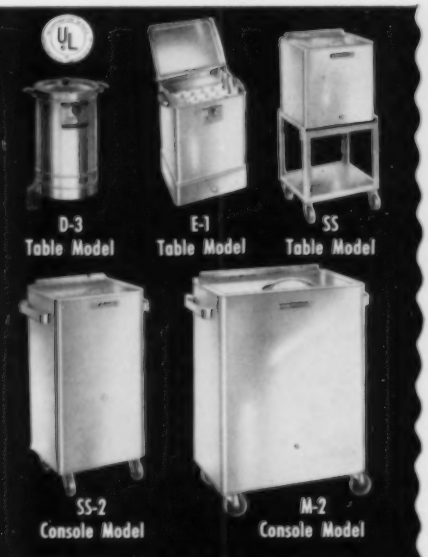

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